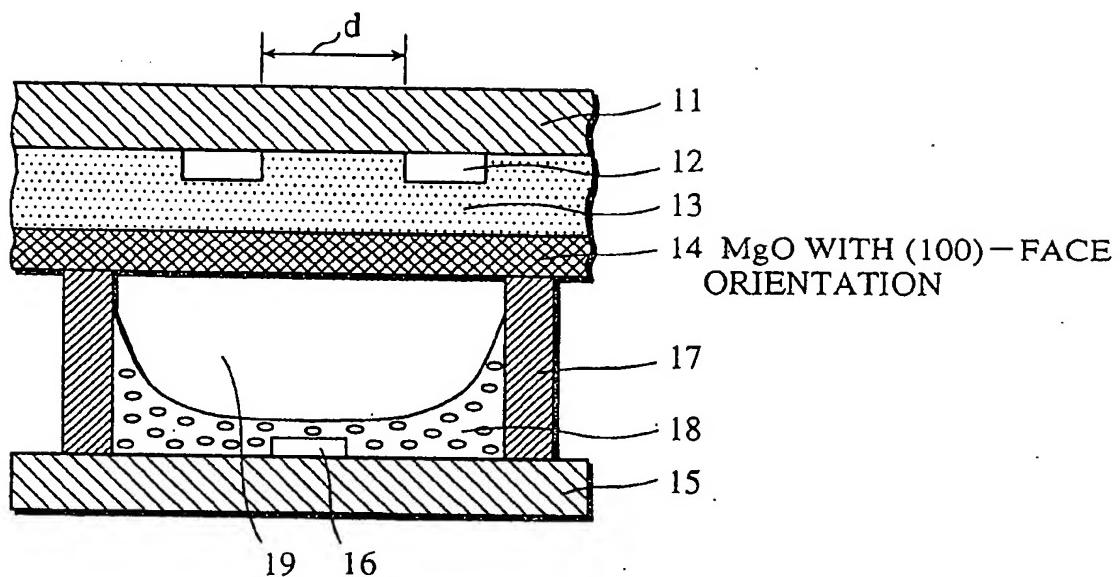


Fig. 2



**Description****BACKGROUND OF THE INVENTION**5      **(1) Field of the Invention**

**[0001]** This invention relates to a plasma display panel used as a display device and the method of producing the display panel, specifically to a plasma display panel suitable for a high-quality display.

10     **(2) Description of the Prior Art**

**[0002]** Recently, as the demand for high-quality large-screen TVs such as high-vision TVs have increased, displays suitable for such TVs, such as Cathode Ray Tube (CRT), Liquid Crystal Display (LCD), and Plasma Display Panel (PDP), have been developed.

15    **[0003]** CRTs have been widely used as TV displays and excel in resolution and picture quality. However, the depth and weight increase as the screen size increases. Therefore, CRTs are not suitable for large screen sizes exceeding 40 inch. LCDs consume a small amount of electricity and operate on a low voltage. However, producing a large LCD screen is technically difficult, and the viewing angles of LCDs are limited.

20    **[0004]** On the other hand, it is possible to make a PDP with a large screen with a short depth, and 40-inch PDP products have already been developed.

**[0005]** PDPs are divided into two types: Direct Current (DC) and Alternating Current (AC). Currently, PDPs are mainly AC-type since they are suitable for large screens.

**[0006]** Fig. 1 is a sectional view of a conventional AC PDP. In the drawing, front cover plate 1, with display electrodes 2 put thereon, is covered by dielectrics glass layer 3 which is lead glass, namely, PbO-B<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> glass.

25    **[0007]** Set on back plate 5 are address electrode 6, partition walls 7, and fluorescent substance layer 8 consisting of red, green, or blue ultraviolet excited fluorescent substance. Discharge gas is charged in discharge space 9 which is sealed with dielectrics glass layer 3, back plate 5, and partition walls 7.

**[0008]** The discharge gas is generally helium (He), xenon (Xe), or mixture of neon (Ne) and Xe. The amount of Xe is generally set to a range from 0.1 to 5% by volume, preventing the drive voltage of the circuit from becoming too high.

30    **[0009]** Also, the charging pressure of the discharge gas is generally set to a range from 100 to 500Torr so that the discharge voltage is stable (e.x., M. Nobrio, T. Yoshioka, Y. Sano, K. Nunomura, SID94' Digest, pp727-730, 1994).

**[0010]** PDPs have the following problems concerning brightness and life.

35    **[0011]** Currently, PDPs for 40-42-inch TV screens generally have a brightness of about 150-250cd/m<sup>2</sup> for National Television System Committee (NTSC) standard (number of pixels being 640X480, cell pitch 0.43mmX1.29mm, square of one cell 0.55mm<sup>2</sup>) (Function & Materials, Feb., 1996, Vol.16, No.2, page 7).

**[0012]** On the contrary, in 42-inch high-vision TVs, number of pixels is 1,920X1,125, cell pitch 0.15mmX0.48mm, and square of one cell 0.072mm<sup>2</sup>. This square of one cell is 1/7-1/8 of that of NTSC standard. Therefore, it is expected that if PDP for 42-inch high-vision TV is made with the conventional cell construction, the screen brightness decreases to 30-40cd/m<sup>2</sup>.

40    **[0013]** Accordingly, to acquire, in a PDP used for a 42-inch high-vision TV, the same brightness as that of a current NTSC CRT (500cd/m<sup>2</sup>), the brightness of each cell should be increased about 12-15 times.

**[0014]** In these circumstances, it is desired that the techniques for increasing the brightness of PDP cells are developed.

45    **[0015]** The light-emission principle in PDP is basically the same as that in fluorescent light: a discharge lets the discharge gas emit ultraviolet light; the ultraviolet light excites fluorescent substances; and the excited fluorescent substances emit red, green, and blue lights. However, since discharge energy is not effectively converted to ultraviolet light and conversion ratio in fluorescent substance is low, it is difficult for PDPs to provide brightness as high as that of fluorescent lights.

50    **[0016]** It is disclosed in Applied Physics, Vol.51, No.3, 1982, pp344-347 as follows: in PDP with He-Xe or Ne-Xe gas, only about 2% of the electric energy is used in ultraviolet light, and about 0.2% of the electric energy is used in visible rays (Optical Techniques Contact, Vol.34, No.1, 1996, page 25 and FLAT PANEL DISPLAY 96, Parts 5-3, NHK Techniques Study, 31-1, 1979, page 18).

**[0017]** Accordingly, to increase light-emission efficiency is considered as important in increasing the brightness of PDP cells.

55    **[0018]** Now, regarding to the PDP life, the following are generally considered to determine the PDP life: (1) the fluorescent substance layer deteriorates since plasma is confined to a small discharge space to generate ultraviolet light; and (2) the dielectrics glass layer deteriorates due to sputtering by gas discharges. As a result, methods for extending the fluorescent substance life or preventing the deterioration of dielectrics glass layer are studied.

[0019] As shown in Fig.1, in conventional PDPs, protecting layer 4 consisting of magnesium oxide (MgO) is formed on the surface of dielectrics glass layer 3 with a vacuum vapor deposition method to prevent the dielectrics glass layer from deteriorating.

[0020] It is desirable that protecting layer 4 has high sputtering resistance and emits a large amount of secondary electron. However, it is difficult for magnesium oxide layer formed by the vacuum vapor deposition method to obtain a protective layer having enough sputtering resistance. There is also a problem that discharges decrease the amount of secondary electron emitted.

#### SUMMARY OF THE INVENTION

[0021] It is therefore the first object of the present invention to provide a PDP with improved panel brightness which is achieved by improving the efficiency in conversion from discharge energy to visible rays. It is the second object of the present invention to provide a PDP with improved panel life which is achieved by improving the protecting layer protecting the dielectrics glass layer.

[0022] To achieve the first object, the present invention sets the amount of Xe in the discharge gas to the range of 10% by volume to less than 100% by volume, and sets the charging pressure for the discharge gas to the range of 500 to 760Torr which is higher than conventional charging pressures. With such construction, the panel brightness increases. The assumed reasons for it are as follows: the increase in the amount of Xe in the discharge space increases the amount of ultraviolet light emitted; the ratio of excitation wavelength (173nm of wavelength) by molecular beam of Xe molecules in the emitted ultraviolet light increases; and this increases the efficiency of a conversion from fluorescent substance to visible rays.

[0023] Also, to achieve the second object, the present invention has, on the surface of the dielectrics glass layer, a protecting layer consisting of an alkaline earth oxide with (100)-face or (110)-face orientation.

[0024] The conventional protecting layer of magnesium oxide formed by vacuum vapor deposition method (electron-beam evaporation method) has (111)-crystal-face orientation. Compared to this, the protecting layer of an alkaline earth oxide with (100)-face or (110)-face orientation is dense, has high sputtering resistance, and emits a great amount of secondary electron.

[0025] Accordingly, the present invention prevents deterioration of the dielectrics glass layer and keeps the discharge voltage low.

[0026] Also, such effects are further improved by using thermal Chemical Vapor Deposition (CVD) method or plasma enhanced CVD method, both of which have not been used as methods of forming protecting layers, to form an alkaline earth oxide with (100)-face orientation.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0027] These and other objects, advantages and features of the invention will become apparent from the following description thereof taken in conjunction with the accompanying drawings which illustrate a specific embodiment of the invention. In the drawings:

- Fig.1 is a sectional view of a conventional AC PDP;
- Fig.2 is a sectional view of an AC PDP described in an embodiment of the present invention;
- Fig.3 shows a CVD apparatus used for forming protecting layer 14;
- Fig.4 is a graph showing the relation between the wavelength and amount of the ultraviolet light for each charging pressure, the ultraviolet light being emitted from Xe in He-Xe gas used as a discharge gas in a PDP;
- Figs.5(a)-(c) shows relation between excitation wavelength and relative radiation efficiency for each color of fluorescent substance;
- Fig.6 is a graph showing relation between charging pressure P of the discharge gas and discharge start voltage Vf for two values of distance d, d being a distance between dielectrics electrodes in a PDP; and
- Fig.7 shows an ion/electron beam irradiating apparatus which is used for forming a protecting layer in the PDP of Embodiment 3.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

{Embodiment 1}

<Structure and Production Method>

[0028] Fig.2 is a sectional view of a discharge PDP of the present embodiment. Though Fig.2 shows only one cell,

a PDP includes a number of cells each of which emits red, green, or blue light.

[0029] The present PDP includes: a front panel which is made up of front glass substrate 11 with display electrodes 12 and dielectrics glass layer 13 thereon; and a back panel which is made up of back glass substrate 15 with address electrode 16, partition walls 17, and fluorescent substance layer 18, the front panel and back panel being bonded together. Discharge space 19, which is sealed with the front panel and back panel, is charged with a discharge gas. The present PDP is made as follows.

#### Producing the Front Panel

10 [0030] The front panel is made by forming display electrodes 12 onto front glass substrate 11, covering it with dielectrics glass layer 13, then forming protecting layer 14 on the surface of dielectrics glass layer 13.

[0031] In the present embodiment, discharge electrodes 12 are silver electrodes which are formed by transferring a paste for the silver electrodes onto front glass substrate 11 with screen printing then baking them. Dielectrics glass layer 13, being lead glass, is composed of 75% by weight of lead oxide (PbO), 15% by weight of boron oxide (B<sub>2</sub>O<sub>3</sub>), and 10% by weight of silicon oxide (SiO<sub>2</sub>). Dielectrics glass layer 13 is also formed with screen printing and baking.

15 [0032] Protecting layer 14 consists of an alkaline earth oxide with (100)-face orientation and is dense. The present embodiment uses a CVD method (thermal CVD method or plasma enhanced CVD method) to form such a dense protecting layer consisting of magnesium oxide with (100)-face orientation. The formation of the protecting layer with the CVD method will be described later.

#### Producing the Back Panel

20 [0033] The back panel is made by transferring the paste for the silver electrodes onto back glass substrate 15 by screen printing then baking back glass substrate 15 to form address electrodes 16 and by attaching partition walls 17 made of glass to back glass substrate 15 with a certain pitch. Fluorescent substance layer 18 is formed by inserting one of a red fluorescent substance, a green fluorescent substance, a blue fluorescent substance into each space surrounded by partition walls 17. Any fluorescent substance generally used for PDPs can be used for each color. The present embodiment uses the following fluorescent substances:

red fluorescent substance	(Y <sub>x</sub> Gd <sub>1-x</sub> )BO <sub>3</sub> : Eu <sup>3+</sup>
green fluorescent substance	BaAl <sub>12</sub> O <sub>19</sub> : Mn
blue fluorescent substance	BaMgAl <sub>14</sub> O <sub>23</sub> : Eu <sup>2+</sup>

#### Producing a PDP by Bonding Panels

35 [0034] A PDP is made by bonding the above front panel and back panel with sealing glass, at the same time excluding the air from discharge space 19 partitioned by partition walls 17 to high vacuum (8X10<sup>-7</sup>Torr), then charging a discharge gas with a certain composition into discharge space 19 at a certain charging pressure.

[0035] In the present embodiment, cell pitch is under 0.2mm and distance between electrodes "d" is under 0.1mm, 40 making the cell size of the PDP conform to 40-inch high-vision TVs.

[0036] The discharge gas is composed of He-Xe gas or Ne-Xe gas, both of which have been used conventionally. However, the amount of Xe is set to 10% by volume or more and the charging pressure to the range of 500 to 700Torr.

#### Forming the Protecting Layer with the CVD Method

45 [0037] Fig.3 shows a CVD apparatus used for forming protecting layer 14.

[0038] For the CVD apparatus, either of the thermal CVD method and plasma enhanced CVD method is applicable. CVD apparatus 25 includes heater 26 for heating glass substrate 27 (equivalent to front glass substrate 11 with display electrodes 12 and dielectrics glass layer 13 as shown in Fig.2). The pressure inside CVD apparatus 25 can be reduced 50 by venting apparatus 29. CVD apparatus 25 also includes high-frequency power 28 for generating plasma in CVD apparatus 25.

[0039] Ar-gas cylinders 21a and 21b supply argon (Ar) gas, which is used as a carrier, to CVD apparatus 25 respectively via bubblers 22 and 23.

[0040] Bubbler 22 stores a metal chelate of alkaline earth oxide used as the source and heats it. The metal chelate is transferred to CVD apparatus 25 when it is evaporated by the argon gas blown on it through Ar-gas cylinder 21a.

[0041] Bubbler 23 stores a cyclopentadienyl compound of alkaline earth oxide used as the source and heats it. The cyclopentadienyl compound is transferred to CVD apparatus 25 when it is evaporated by the argon gas blown on it through Ar-gas cylinder 21b.

[0042] Oxygen cylinder 24 supplies oxygen ( $O_2$ ) used, as a reaction gas to CVD apparatus 25.

[0043] (1) For thermal CVDs performed with the present CVD apparatus, glass substrate 27 is put on heating unit 26 with the dielectrics glass layer on glass substrate 27 to be heated with a certain temperature (350 to 400°C. See Table 1 "HEATING TEMPERATURE FOR GLASS SUBSTRATE"). At the same time, the pressure in the reaction container is reduced by venting apparatus 29 (by about several tens Torr).

[0044] Bubbler 22 or 23 is used to heat the metal chelate or cyclopentadienyl compound of alkaline earth oxide used as the source to a certain temperature (See Table 1, "TEMPERATURE OF BUBBLER"). At the same time, Ar gas is sent to bubbler 22 or 23 through Ar-gas cylinder 21a or 21b and oxygen is sent through cylinder 24.

[0045] The metal chelate or cyclopentadienyl compound reacts with oxygen in CVD apparatus 25 to form a protecting layer consisting of an alkaline earth oxide on the surface of glass substrate 27.

[0046] (2) For plasma enhanced CVDs performed with the present CVD apparatus, the procedure is almost the same as that of the thermal CVD described above. However, glass substrate 27 is heated by heating unit 26 with temperature ranging from 250 to 300°C (See Table 1, "HEATING TEMPERATURE FOR GLASS SUBSTRATE"). At the same time, the pressure in the reaction container is reduced to about 10Torr by venting apparatus 29. Under the circumstances, a protecting layer consisting of an alkaline earth oxide is formed by driving high-frequency power 28 to apply high-frequency electric field of 13.56MHz, generating plasma in CVD apparatus 25.

[0047] Conventionally, the thermal CVD method or plasma enhanced CVD method has not been used for forming a protecting layer. One of the reasons for not using these methods is that no appropriate source for these methods was not found. The present inventors have made it possible to form a protecting layer with the thermal CVD method or plasma enhanced CVD method by using the sources described below.

[0048] The source (metal chelate or cyclopentadienyl compound) supplied through bubblers 22 and 23:

alkaline earth dipivaloylmethane compound  $M(C_{11}H_{19}O_2)_2$ ,

alkaline earth acetylacetone compound  $M(C_5H_7O_2)_2$ ,

alkaline earth trifluoroacetylacetone compound  $M(C_5H_5F_3O_2)_2$ , and

alkaline earth cyclopentadiene compound  $M(C_5H_5)_2$ , where "M" represents an alkaline earth element.

[0049] In the present embodiment, the alkaline earth is magnesium. Therefore, the sources are as follows: magnesium dipivaloyl methane  $Mg(C_{11}H_{19}O_2)_2$ , magnesium acetylacetone  $Mg(C_5H_7O_2)_2$ , magnesium trifluoroacetylacetone  $Mg(C_5H_5F_3O_2)_2$ , and cyclopentadienyl magnesium  $Mg(C_5H_5)_2$ .

[0050] The protecting layer formed with the thermal CVD method or plasma enhanced CVD method allows the crystals of the alkaline earth oxides to grow slowly to form a dense protecting layer consisting of an alkaline earth oxide with (100)-face orientation.

### 35 Effects of Protecting Layer of Magnesium Oxide with (100)-Face Orientation

[0051] The conventional protecting layer of magnesium oxide formed by vacuum vapor deposition method (electron-beam evaporation method) has (111)-crystal-face orientation according to X-ray analysis (See No.15 in Table 2 and Nos.67 and 69 in Table 4). Compared to this, the protecting layer of a magnesium oxide with (100)-face orientation has the following characteristics and effects:

(1) the magnesium oxide with (100)-face orientation extends PDP life since it protects dielectrics glass layer due to its sputtering resistance owing to its density;

(2) the magnesium oxide with (100)-face orientation reduces driving voltage of PDP and improves panel brightness since it has a large emission coefficient ( $\gamma$  value) of secondary electron;

(3) The magnesium oxide with (111)-face orientation tends to react with the water content in the air to form hydroxides since it forms faces with the highest surface energy among a variety of faces with orientation (see Surface Techniques, Vol.41, No.4, 1990, page 50 and Japanese Laid-Open Patent Application No.5-342991). Accordingly, magnesium oxide with (111)-face orientation has a problem that the formed hydroxides decompose during a discharge and reduce the amount of the emission of secondary electron. On the other hand, the protecting layer of a magnesium oxide with (100)-face orientation is to a large extent immune to this problem.

(4) The magnesium oxide with (111)-face orientation has a heat resistance of up to 350°C. On the other hand, since the protecting layer of a magnesium oxide with (100)-face orientation has a higher heat resistance, heat treatment is carried out at a temperature of about 450°C when the front cover plate and the back plate are bonded.

(5) With the protecting layer of a magnesium oxide with (100)-face orientation, aging after bonding of panels is comparatively short.

[0052] These characteristics and effects are especially noticeable in the protecting layer of a magnesium oxide with

(100)-face orientation formed with the thermal CVD method or plasma enhanced CVD method.

#### Relation between Xe Amount, Charging Pressure, and Brightness

- 5 [0053] The panel brightness improves by setting the amount of Xe in the discharge gas to 10% by volume or more and by setting the charging pressure for the discharge gas to the range of 500 to 760Torr. The following are considered to be the reasons.

##### (1) Increase in the Amount of Ultraviolet Light

- 10 [0054] Setting the amount of Xe in the discharge gas to 10% by volume or more and setting the charging pressure for the discharge gas to the range of 500 to 760Torr increase the amount of Xe in the discharge space, raising the amount of ultraviolet light emitted.

- 15 [0055] Conventionally, Xe emitted ultraviolet light mainly at 147nm (resonance line of Xe molecule) since the amount of Xe in the discharge gas was set to 5% by volume or less and the charging pressure for the discharge gas to less than 500Torr. However, by setting the amount of Xe in the discharge gas to 10% by volume or more and by setting the charging pressure for the discharge gas to the range of 500 to 760Torr, ultraviolet light emission at 173nm (molecular beam of Xe molecule), being a long wavelength, increases, improving the conversion efficiency of fluorescent substance (see a material published by Plasma Study Group in Electrical Engineers of Japan, May 9, 1995).

- 20 [0056] The above reason will be backed up by the following description.

- 25 [0057] Fig.4 is a graph showing the change in relation between the wavelength and amount of the ultraviolet light for each charging pressure, the ultraviolet light being emitted from Xe in He-Xe gas used as a discharge gas in a PDP. This graph is introduced in O Plus E, No.195, 1996, page 99.

- [0058] It is apparent from Fig.4 that if charging pressure is low, Xe emits ultraviolet light mainly at 147nm (resonance line of Xe molecule) and that as the charging pressure increases, the ratio of ultraviolet light emission at 173nm increases.

- 30 [0059] Figs.5(a)-(c) show relation between excitation wavelength and relative radiation efficiency for each color of fluorescent substance. This graph is included in O Plus E, No.195, 1996, page 99. It is apparent from this drawing that the relative radiation efficiency is higher at 173nm of wavelength than at 147nm for every color of fluorescent substrate.

#### Relation between Discharge Gas Charging Pressure, Distance "d" between Discharge Electrodes, and Panel Driving Voltage

- 35 [0060] The amount of Xe in the discharge gas and the charging pressure for the discharge gas are set to higher levels in the present embodiment. However, generally, this is considered to bring an inconvenience in that the PDP driving voltage increases since discharge start voltage "Vf" increases as the amount of Xe in the discharge gas or the charging pressure increases (see Japanese Laid-Open Patent Application No.6-342631, column 2, pp 8-16 and 1996 Electrical Engineers of Japan National Conference Symposium, S3-1, Plasma Display Discharge, March, 1996).

- 40 [0061] However, such an inconvenience does not always occur. As is described below, the driving voltage may be low even if the charging pressure is set to a high level if distance "d" between discharge electrodes is set to a comparatively small value.

- 45 [0062] As described in Electronic Display Device, Ohm Corp., 1984, pp 113-114, the discharge start voltage Vf may be represented as a function of P multiplied by d which is called the Paschen's Law.

- [0063] Fig.6 shows relation between charging pressure P of the discharge gas and discharge start voltage Vf for two values of distance d: d = 0.1mm; and d = 0.05mm.

- 50 [0064] As shown in this graph, discharge start voltage Vf corresponding to charging pressure P of the discharge gas is represented by a curve including a minimum.

- [0065] Charging pressure P, being equal to the minimum, increases as d decreases. The curve of graph "a" (d=0.1mm) passes through the minimum at 300Torr, the curve of graph "b" (d=0.05mm) at 600Torr.

- [0066] It is apparent from the above description that an appropriate value corresponding to distance d between discharge electrodes should be set as the charging pressure in order to keep PDP driving voltage low.

- 55 [0067] Also, it is possible to say that if distance d between discharge electrodes is set to 0.1mm or less (desirably to about 0.05mm), PDP driving voltage is kept low even if the charging pressure for the discharge gas is set to the range of 500 to 760Torr.

- [0068] As is apparent from the above description, the PDP of the present embodiment shows high panel brightness

since the amount of Xe in the discharge gas is set to 10% by volume or more and the charging pressure for the discharge gas is set to the range of 500 to 760Torr. Also, the driving voltage of the PDP of the present embodiment is kept low since distance d between discharge electrodes is set to 0.1mm or less. Furthermore, the PDP of the present embodiment has a long life since it includes a protecting layer of a dense magnesium oxide with (100)-face orientation which shows good effects in protection.

## &lt;Examples 1-9&gt;

[0069] Table 1 shows PDP Examples 1-9 which were made according to the present embodiment. The cell size of the PDP was set as follows: the height of partition walls 7 is 0.15mm, the distance between partition walls 7 (cell pitch) 0.15mm, and distance d between discharge electrodes 12 0.05mm.

[0070] Dielectrics glass layer 13, being lead glass, was formed by transferring a mixture of 75% by weight of lead oxide (PbO), 15% by weight of boron oxide (B<sub>2</sub>O<sub>3</sub>), 10% by weight of silicon oxide (SiO<sub>2</sub>), and organic binder (made by dissolving 10% ethyl cellulose in  $\alpha$ -terpineol) onto front glass substrate 11 with display electrodes 12 by screen printing and baking them for 10 minutes at 520°C. The thickness of dielectricsglass layer 13 was set to 20 $\mu$ m.

[0071] The ratio of He to Xe in the discharge gas and the charging pressure were set as shown in Table 1 except that the ratio of He in the discharge gas was set to less than 10% by volume for Examples 7 and 9 and that the charging pressure for the discharge gas was set to less than 500Torr for Examples 7 and 8.

[0072] Regarding to the method of forming the protecting layer, the thermal CVD method was applied to Examples 1, 3, 5, and 7-9, and the plasma enhanced CVD method to Examples 2, 4, and 6. Also, magnesium dipivaloyl methane Mg(C<sub>11</sub>H<sub>19</sub>O<sub>2</sub>)<sub>2</sub> was used as the source for Examples 1, 2, 7, 8, and 9, magnesium acetylacetone Mg(C<sub>5</sub>H<sub>7</sub>O<sub>2</sub>)<sub>2</sub> for Examples 3 and 4, and cyclopentadienyl magnesium Mg(C<sub>5</sub>H<sub>5</sub>)<sub>2</sub> for Examples 5 and 6.

[0073] The temperature of bubblers 22 and 23 and the heating temperature of glass substrate 27 were set as shown in Table 1.

[0074] For the thermal CVD method, Ar gas was provided for one minute with the flow rate of 1 l/min., oxygen for one minute with the flow rate of 2 l/min. Also, the layer forming speed was adjusted to 1.0 $\mu$ m/min., the thickness of magnesium oxide protecting layer to 1.0 $\mu$ m.

[0075] For the plasma enhanced CVD method, Ar gas was provided for one minute with the flow rate of 1 l/min., oxygen for one minute with the flow rate of 2 l/min. High-frequency wave was applied for one minute with 300W. Also, the layer forming speed was adjusted to 0.9 $\mu$ m/min., the thickness of magnesium oxide protecting layer to 0.9 $\mu$ m.

[0076] With the X-ray analysis of the protecting layers of Examples 1-9, which had been formed as described above, it was confirmed for each Example that the crystals of magnesium oxides have (100)-face orientation.

## {Embodiment 2}

[0077] The overall structure and production method of the PDP of the present embodiment is the same as that of Embodiment 1 except that a dense protecting layer consisting of magnesium oxide with (100)-face orientation is formed with a printing method shown below.

## &lt;Forming of Protecting Layer with Printing Method&gt;

[0078] A dense protecting layer consisting of magnesium oxide with (100)-face orientation is formed by transferring magnesium salt paste with a plate-shaped crystal structure onto the dielectrics glass layer and baking it.

[0079] The magnesium salts with a plate-shaped crystal structure for use are magnesium carbonate (MgCO<sub>3</sub>), magnesium hydroxide (Mg(OH)<sub>2</sub>), magnesium oxalate (MgC<sub>2</sub>O<sub>4</sub>), etc. The production methods of these magnesium salts are described below in Examples 10-14.

[0080] The dense protecting layer consisting of magnesium oxide with (100)-face orientation formed by the printing method has the same effects as that formed with the method shown in Embodiment 1.

## &lt;Examples 10-15&gt;

[0081] Table 2 shows PDP Examples 10-15 whose cell size and distance d between discharge electrodes 12 were set in the same way as PDP Examples 1-9.

[0082] Examples 10-14 were made according to the present embodiment. Example 15 includes a protecting layer formed by a conventional vacuum vapor deposition method.

[0083] The magnesium oxalate (MgC<sub>2</sub>O<sub>4</sub>) with a plate-shaped crystal structure used for Example 10 was produced by dissolving ammonium oxalate (NH<sub>4</sub>HC<sub>2</sub>O<sub>4</sub>) in magnesium chloride (MgCl<sub>2</sub>) aqueous solution to make magnesium oxalate aqueous solution then heating it at 150°C.

[0084] The magnesium carbonate with a plate-shaped crystal structure used for Example 11 was produced by dissolving ammonium carbonate ( $(\text{NH}_4)_2\text{CO}_3$ ) in magnesium chloride ( $\text{MgCl}_2$ ) aqueous solution to make magnesium carbonate ( $\text{MgCO}_3$ ), then heating it in carbonic acid gas to 900°C.

[0085] The magnesium hydroxide with a plate-shaped crystal structure used for Examples 12-14 was produced by dissolving sodium hydroxide ( $\text{NaOH}$ ) in magnesium chloride ( $\text{MgCl}_2$ ) aqueous solution to make magnesium hydroxide ( $\text{Mg(OH)}_2$ ), then pressurizing and heating it in sodium hydroxide at 5 atmosphere pressures and 900°C.

[0086] Each of the magnesium salts with a plate-shaped crystal structure made as described above was mixed with an organic binder (made by dissolving 10% ethyl cellulose in 90% by weight of terpineol) by using a three-roller mill to establish a paste, then the paste was transferred onto the dielectrics glass layer by screen printing with a thickness of 3.5 $\mu\text{m}$ .

[0087] After baking each of these for 20 minutes at 500°C, a protecting layer consisting of magnesium oxide with a thickness of about 1.7 $\mu\text{m}$  was formed.

[0088] With the X-ray analysis of the protecting layers of Examples 10-14, which had been formed as described above, it was confirmed for each Example that the crystals of magnesium oxides had (100)-face orientation.

[0089] For Example 15, a protecting layer was formed by the vacuum vapor deposition method, that is, by heating magnesium oxide with electron beam. With the X-ray analysis of the protecting layer, it was confirmed that the crystals of magnesium oxides had (111)-face orientation.

{Embodiment 3}

[0090] The overall structure and production method of the PDP of the present embodiment is the same as that of Embodiment 1 except that a gas including Ar or Kr, namely Ar-Xe, Kr-Xe, Ar-Ne-Xe, Ar-He-Xe, Kr-Ne-Xe, or kr-He-Xe gas is used as the discharge gas.

[0091] By mixing Ar or Kr with the discharge gas, the panel brightness is further improved. The reason is considered that the ratio of ultraviolet light emission at 173nm increases further.

[0092] Here, it is desirable that the amount of Xe is set to the range from 10 to 70% by volume since the driving voltage tends to rise if the amount exceeds 70% by volume.

[0093] Also, for three-element discharge gases such as Ar-Ne-Xe, Ar-He-Xe, Kr-Ne-Xe, and kr-He-Xe gases, it is desirable that the amount of Kr, Ar, He, or Ne should be in the range of 10 to 50% by volume.

[0094] In the present embodiment, in forming a protecting layer, a method for evaporating a magnesium oxide with (110)-face orientation onto the dielectrics glass layer with irradiation of ion or electron beam is used as well as the thermal CVD or plasma enhanced CVD method for forming magnesium oxide with (100)-face orientation as described in Embodiment 1. The method is described below.

**<Method for Evaporating Alkaline Earth Oxide onto Dielectrics Glass Layer by Use of Ion or Electron Beam Irradiation to Form Protecting Layer>**

[0095] Fig.7 shows an ion/electron beam irradiating apparatus which is used for forming a protecting layer in the PDP of the present embodiment.

[0096] The ion/electron beam irradiating apparatus includes vacuum chamber 45 to which glass substrate 41 with a dielectrics glass layer is attached. Vacuum chamber 45 also includes electron gun 42 for evaporating an alkaline earth oxide (in the present embodiment, magnesium oxide).

[0097] Ion gun 43 irradiates ion beam to vapor of the alkaline earth oxide which has been evaporated by electron gun 42. Electron gun 44 irradiates electron beam to vapor of the alkaline earth oxide evaporated by electron gun 42.

[0098] The following description shows how to evaporate the alkaline earth oxide onto the dielectrics glass layer by irradiating ion or electron beam to vapor using the ion/electron beam irradiating apparatus of the present invention.

[0099] First, glass substrate 41 with a dielectrics glass layer is set in chamber 45 then crystals of an alkaline earth oxide are put in electron gun 42.

[0100] Secondly, chamber 45 is evacuated then substrate 41 is heated (150°C). Electron gun 42 is used to evaporate the alkaline earth oxide. At the same time, ion gun 43 or electron gun 44 is used to irradiate argon ion or electron beam towards substrate 41. It forms a protecting layer of an alkaline earth oxide.

[0101] The crystals of the alkaline earth oxide grow slowly and a dense protecting layer consisting of an alkaline earth oxide with (110)-face orientation is formed when, as is described above, the alkaline earth oxide is evaporated onto the dielectrics glass layer by irradiation of the ion or electron beam. The formed protecting layer shows almost the same effects as the dense protecting layer of an alkaline earth oxide with (100)-face orientation formed in Embodiment 1.

## &lt;Examples 16-34&gt;

**[0102]** Table 3 shows PDP Examples 16-34 which were made according to the present embodiment. Refer to "DISCHARGE GAS TYPE AND RATIO" column in the table for the discharge gas compositions, and "GAS CHARGING PRESSURE" column for charging pressures.

**[0103]** The protecting layer of Examples 16 and 27 were formed as described in Embodiment 1 using magnesium dipivaloyl methane  $Mg(C_{11}H_{19}O_2)_2$  as the source with the thermal CVD method, and Examples 17, 23, 24, 28, 32, and 33 with the plasma enhanced CVD method.

**[0104]** For Examples 18, 21, 22, 25, 26, and 34, ion beam (current of 10mA) was irradiated, and for Examples 19, 20, 30, and 31, electron beam (10mA), to evaporate a magnesium oxide onto the dielectrics glass layer to form a protecting layer with a layer thickness of 5000A.

**[0105]** With the X-ray analysis of the protecting layers which had been formed by evaporating magnesium oxides onto the dielectrics glass layer with irradiation of ion or electron beam, it was confirmed that the crystals of the magnesium oxides had (110)-face orientation.

## 15 {Embodiment 4}

**[0106]** The overall structure and production method of the PDP of the present embodiment is the same as that of Embodiment 1 except that the cell pitch is set to a larger value and the amount of Xe in a He-Xe gas used as the discharge gas is set to less than 10% by volume. Note that the distance between electrodes "d" is set to an equal or larger value.

**[0107]** In the present embodiment, alkaline earth oxides with (100)-face orientation other than magnesium oxide ( $MgO$ ) are formed as the protecting layers, such as beryllium oxide ( $BeO$ ), calcium oxide ( $CaO$ ), strontium oxide ( $SrO$ ), and barium oxide ( $BaO$ ).

**[0108]** These protecting layers are formed by using appropriate sources for respective alkaline earths with the thermal or plasma enhanced CVD method described in Embodiment 1.

**[0109]** The discharge electrodes formed on the front glass substrate includes a tin oxide-antimony oxide or an indium oxide-tin oxide.

**[0110]** The protecting layer of beryllium oxide, calcium oxide, strontium oxide, or barium oxide with (100)-face orientation has almost the same effects as the magnesium oxide with (100)-face orientation formed in Embodiment 1.

## &lt;Examples 35-66&gt;

**[0111]** Table 4 shows PDP Examples 35-66 which were made according to the present embodiment. The height of the partition walls was set to 0.2mm, the distance between partition walls (cell pitch) 0.3mm, and distance d between discharge electrodes 0.05mm. The discharge gas was a He-Xe mixture gas including 5% by volume of Xe, and the charging pressure was set to 500Torr.

**[0112]** The discharge electrodes, which were made with sputtering and photo-lithography methods, consist of indium oxide ( $In_2O_3$ ) including 10% by weight of tin oxide ( $SnO_2$ ).

**[0113]** The protecting layers were made with the thermal or plasma enhanced CVD method from metal chelate or cyclopentadienyl compounds of the alkaline earth oxides shown in Table 4 "CVD SOURCE" column. The formed layers were of magnesium oxide, beryllium oxide, calcium oxide, strontium oxide, or barium oxide as shown in "ALKALINE EARTH OXIDE" column.

**[0114]** With the X-ray analysis of the protecting layers, it was confirmed that each Example had (100)-face orientation.

## 45 &lt;Reference&gt;

**[0115]** Examples 67-69 shown in Table 4 were made in the same way as Examples 35-66. However, the protecting layers of Examples 67-69 were formed with different methods: for Example 67, the vacuum vapor deposition method for evaporating magnesium oxide onto the dielectrics glass layer by heating magnesium oxide with electron beam was used; for Example 68, the sputtering performed on magnesium oxide as the target; and for Example 69, the screen printing with magnesium oxide paste.

**[0116]** With the X-ray analysis of the protecting layers, it was confirmed that magnesium oxide protecting layers of Examples 67 and 69 had (111)-face orientation. It was also confirmed that magnesium oxide protecting layer of Examples 68 had (100)-face orientation. However, the protecting layer of Example 68 is not considered as dense since it was formed with the sputtering.

## EP 1 221 711 A2

<Experiment 1: Measuring Ultraviolet Light Wavelength and Panel Brightness (Initial Value)>

### Experiment Method

- 5 [0117] For Examples 1-15, the ultraviolet light wavelength and panel brightness (initial value) were measured when they were operated on 150V of discharge maintenance voltage and 30KHz of frequency.

### Results and Analysis

- 10 [0118] As shown in Tables 1-3, resonance lines of Xe with a wavelength of 147nm were mainly observed from examples 7-9, showing low panel brightness (around 200cd/m<sup>2</sup>), while molecular beams of Xe with a wavelength of 173nm were mainly observed from examples 1-6 and 10-34, showing high panel brightness (around 400cd/m<sup>2</sup> or more). Of these, Examples 16-34 showed the highest panel brightness (around 500cd/m<sup>2</sup> or more).

- 15 [0119] It is apparent from the above results that the panel brightness is improved by setting the amount of Xe in discharge gas to 10% by volume or more, charging pressure to 500Torr or more and that the panel brightness is further improved by mixing Kr or Ar with the discharge gas.

- [0120] The panel brightness of example 15 is slightly lower than those of Examples 1-6 and 10-14. The reason is considered that the protecting layer of Example 15 consisting of magnesium oxide with (111)-face orientation emits less secondary electron than that with (100)-face orientation.

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<Experiment 2: Measuring Change Rates of Panel Brightness and Discharge Maintenance Voltage>

### Experiment Method

- 25 [0121] For Examples 1-15 and 35-69, the change rates (change rates from respective initial values after 7,000 hours of operation) of panel brightness and discharge maintenance voltage were measured after they were operated for 7,000 hours on 150V of discharge maintenance voltage and 30KHz of frequency.

- [0122] For Examples 16-34, the change rates of panel brightness and discharge maintenance voltage were measured after they were operated for 5,000 hours on 170V of discharge maintenance voltage and 30KHz of frequency.

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### Results and Analysis

- 35 [0123] As shown in Tables 1 and 2, the panel brightness change rates of examples 1-6 and 10-14 are smaller than those of examples 7-9. Also, as shown in Table 3, the change rates of panel brightness and discharge maintenance voltage of examples 16-34 were small as a whole.

- [0124] It is apparent from the above results that the panel brightness change rate reduces by setting the amount of Xe in discharge gas to 10% by volume or more, charging pressure to 500Torr or more.

- [0125] The change rates of panel brightness and discharge maintenance voltage of examples 1-14 are smaller than those of Example 15. The reason is considered that the protecting layer of magnesium oxide with (111)-face orientation has higher sputtering resistance and higher efficiency in protecting dielectrics glass layer than that with (100)-face orientation.

- [0126] As shown in Table 4, the change rates of panel brightness and discharge maintenance voltage of examples 35-66 are little, and those of examples 67-69 great.

- [0127] The above results show that generally the protecting layer of alkaline earth oxide with (100)-face or (110)-face orientation formed with the thermal CVD method, plasma enhanced CVD method, or vapor deposition method with ion or electron beam irradiation has higher sputtering resistance and higher efficiency in protecting dielectrics glass layer than that with (111)-face orientation. Note that the results of example 67 show that the protecting layer consisting of alkaline earth oxide with (100)-face orientation formed with the sputtering method has high change rates of panel brightness and discharge maintenance voltage and low efficiency in protecting dielectrics glass layer.

- 50 [0128] The reason for the above results is considered that for the alkaline earth oxide of the protecting layer which has been formed by the thermal CVD, plasma enhanced CVD, or a method of evaporating the oxide onto a layer by irradiating ion or electron beam, the crystals grow slowly to form a dense protecting layer with (100)-face or (110)-face orientation; for the protecting layer formed by the sputtering method, the crystals do not grow slowly and the protecting layer does not become dense though it has (100)-face orientation.

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<Others>

[0129]

- 5 - The values in Tables 1-4 in "BUBLER TEMPERATURE," "HEATING TEMPERATURE FOR GLASS SUBSTRATE," "PANEL BAKING TEMPERATURE," "PRINTED LAYER THICKNESS," "Ar GAS FLOW RATE," and "O<sub>2</sub> GAS FLOW RATE" were considered to be optimum for the respective alkaline earth sources.
- 10 - The results of the change rates of panel brightness and dielectrics maintenance voltage shown in Table 4 were obtained from PDPs with 5% by volume of Xe in discharge gas. However, the same results may be obtained from those with 10% by volume or more of Xe.
- 15 - In the above Embodiments, the back panel of the PDPs includes back glass substrate 15 with which partition walls 17 are bonded. However, the present invention is not limited to such construction and may be applied to general AC PDPs such as those having partition walls attached to the front panel.

[0130] Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Therefore, unless such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.

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[TABLE 1]

EXAMPLE No.	PROTECTING LAYER FORMING METHOD	CVD SOURCE TEMPERATURE (°C)	BUBBLER TEMPERATURE (°C)	HEATING TEMPERATURE FOR GLASS SUBSTRATE (°C)	X-RAY ANALYSIS RESULT	DISCHARGE GAS TYPE AND RATIO (%)	GAS PRESSURE (Torr)	ULTRA VIOLET RAY WAVELENGTH (nm) <sup>2</sup>	PANEL BRIGHTNESS (INITIAL VALUE) (cd/m <sup>2</sup> )	CHARACTERISTICS		
										PANEL BRIGHTNESS (%)	PANEL BRIGHTNESS (%)	VOLTAGE (%)
1	THERMAL CVD	Mg(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub>	125	350	{100}-FACE ORIENTATION	He(90)-Xe(10)	500	173nm BY MOLECULAR BEAM	430	-8.4	-8.4	2.4
2	PLASMA ENHANCED CVD	Mg(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub>	125	250	"	He(80)-Xe(20)	600	"	450	-7.8	-7.8	2.2
3	THERMAL CVD	Mg(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub>	185	400	"	He(50)-Xe(50)	650	"	460	-7.5	-7.5	2.3
4	PLASMA ENHANCED CVD	"	"	300	"	He(10)-Xe(90)	700	"	440	-7.0	-7.0	2.4
5	THERMAL CVD	Mg(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	80	350	"	He(1)-Xe(99)	650	"	430	-7.2	-7.2	2.3
6	PLASMA ENHANCED CVD	"	80	250	"	He(30)-Xe(70)	760	"	435	-7.5	-7.5	2.5
7	THERMAL CVD	Mg(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub>	125	350	"	He(98)-Xe(2)	300	147nm BY RESONANCE LINE	205	-9.4	-9.4	2.5
8	"	"	"	"	"	He(80)-Xe(20)	450	"	210	-9.5	-9.5	2.8
9	"	"	"	"	"	He(90)-Xe(5)	550	"	205	-9.8	-9.8	2.9

[TABLE 2]

EXAMPLE No.	SOURCE OF PLATE-SHAPED MgO	PRINTED PLATE-SHAPED MAGNESIUM SALT	GAINED PLATE-SHAPED MAGNESIUM THICKNESS ( $\mu$ m)	PANEL BAKING TEMPERATURE(°C)	X-RAY ANALYSIS RESULT	DISCHARGE GAS TYPE AND RATIO (%)	GAS CHARGING PRESSURE (Tor)	ULTRA VIOLET RAY WAVELENGTH (nm)	CHARACTERISTICS		
									PANEL BRIGHTNESS (INITIAL VALUE)	PANEL BRIGHTNESS (cm <sup>-2</sup> )	CHANGE RATE AFTER 7000,150V,50Hz DISCHARGE MAINTENANCE VOLTAGE(%)
10	MgCl <sub>2</sub> ,NH <sub>4</sub> HC <sub>2</sub> O <sub>4</sub>	MgC <sub>2</sub> O <sub>4</sub>	3.5	500	(100) FACE ORIENTATION	Ne(50)-Xe(50)	650	173nm BY MOLECULAR BEAM	410	-5.8	2.2
11	MgCl <sub>2</sub> ,(NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub>	MgCO <sub>3</sub>	"	"	"	Ne(30)-Xe(70)	700	"	425	-6.5	2.8
12	MgCl <sub>2</sub> ,NaOH	Mg(OH) <sub>2</sub>	"	"	"	Ne(60)-Xe(40)	550	"	430	-7.2	2.6
13	"	"	"	"	"	Ne(1)-Xe(99)	600	"	415	-7.5	2.8
14	"	"	"	"	"	Ne(90)-Xe(10)	760	"	408	-7.2	2.9
15	VACUUM VAPOR DEPOSITION ON MgO WITH ELECTRON BEAM				(100) FACE ORIENTATION	Ne(50)-Xe(50)	650	"	380	-15.8	3.2

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[TABLE 3]

EXAMPLE No.	PROTECTING LAYER FORMING METHOD	CVD SOURCE	BUBBLER TEMPERATURE (°C)	HEATING TEMPERATURE FOR GLASS SUBSTRATE (°C)	X-RAY ANALYSIS RESULT	DISCHARGE GAS TYPE AND RATIO (%)	GAS CHARGING PRESSURE (Torr)	ULTRAVIOLET RAY WAVELENGTH	CHARACTERISTICS CHARGER AFTER 2000 LSV, 20KHz		
									PANEL BRIGHTNESS (%)	DISCHARGE MAINTENANCE VOLTAGE (%)	PANEL BRIGHTNESS (%)
16	Thermal CVD	Mg(C <sub>1</sub> H <sub>9</sub> O) <sub>2</sub>	125	150	(100)-FACE ORIENTATION	Ar(90)-Xe(10)	500	111nm BY MOLECULAR BEAM	501	-6.5	2.0
17	Plasma Enhanced CVD	Mg(C <sub>1</sub> H <sub>9</sub> O) <sub>2</sub>	125	250	"	Ar(50)-Xe(50)	610	"	505	-5.2	1.9
18	Vapor Deposition of MgO by Irradiating Ion Beam		150	(110)-FACE ORIENTATION	Ar(10)-Xe(70)	550	"	502	-5.8	2.1	
19	Vapor Deposition of MgO by Irradiating Electron Beam		"	"	"	"	"	"	498	-6.0	2.2
20	"	"	"	"	"	Kr(90)-Xe(10)	630	"	512	-6.2	2.5
21	Vapor Deposition of MgO by Irradiating Ion Beam		"	"	"	Kr(50)-Xe(50)	550	"	516	-7.1	2.2
22	"	"	"	"	"	Kr(10)-Xe(70)	590	"	513	-6.0	2.3
23	Plasma Enhanced CVD	Mg(C <sub>1</sub> H <sub>9</sub> O) <sub>2</sub>	125	250	(100)-FACE ORIENTATION	Xe(10)-Ar(40)-Ne(50)	760	"	495	-4.2	2.4
24	"	"	"	"	"	Xe(40)-Ar(50)-Ne(10)	610	"	513	-5.8	2.1
25	Vapor Deposition of MgO by Irradiating Ion Beam		150	(110)-FACE ORIENTATION	Ar(10)-Ar(10)-Ne(20)	550	"	508	-5.9	2.3	
26	"	"	"	"	"	Xe(10)-Ar(40)-Ne(50)	520	"	506	-5.2	2.6
27	Thermal CVD	Mg(C <sub>1</sub> H <sub>9</sub> O) <sub>2</sub>	125	150	(100)-FACE ORIENTATION	Xe(40)-Ar(50)-Ne(10)	580	"	518	-5.0	2.5
28	Plasma Enhanced CVD	"	"	250	"	Xe(10)-Ar(10)-Ne(20)	610	"	503	-4.9	2.1
29	"	"	"	"	"	Xe(10)-Ar(40)-Ne(50)	630	"	521	-4.5	2.4
30	Vapor Deposition of MgO by Irradiating Electron Beam		150	(110)-FACE ORIENTATION	Xe(40)-Ar(50)-Ne(10)	700	"	510	-4.3	2.3	
31	"	"	"	"	"	Xe(10)-Ar(10)-Ne(20)	610	"	508	-4.7	2.2
32	Plasma Enhanced CVD	Mg(C <sub>1</sub> H <sub>9</sub> O) <sub>2</sub>	125	250	(100)-FACE ORIENTATION	Xe(10)-Ar(40)-Ne(50)	500	"	518	-5.0	2.7
33	"	"	"	"	"	Xe(40)-Ar(50)-Ne(10)	750	"	511	-4.4	2.6
34	Vapor Deposition of MgO by Irradiating Ion Beam		150	(110)-FACE ORIENTATION	Xe(10)-Ar(10)-Ne(20)	590	"	506	-4.9	2.4	

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[TABLE 4]

EXAMPLE NO.	CVD SOURCE	BUBBLER TEMPERATURE (°C)	HEATING TEMPERATURE FOR GLASS SUBSTRATE (°C)	PROTECTING LAYER FORMING METHOD	Al GAS FLOW RATE (0/min.)	O <sub>2</sub> GAS FLOW RATE (0/min.)	X-RAY ANALYSIS RESULT		ALKALINE EARTH OXIDE DEPOSITION SPEED (μm/min.)	LAYER THICKNESS (μm)	CHARACTERISTICS CHANGE RATE AFTER 700 HOURS (%)
							ALKALINE EARTH OXIDE	CRYSTAL ORIENTATION			
35	MeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	125	150	Thermal CVD	—	2	MoO <sub>3</sub>	III/IV face orientation	1.0	1.0	-9.5%
36	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	7	250	Plasma Enhanced CVD	—	—	—	—	0.9	0.9	-8.5%
37	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	110	350	Thermal CVD	—	—	BeO	—	0.8	0.8	-10.2%
38	CaC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	7	250	Plasma Enhanced CVD	—	—	—	—	0.7	0.7	-10.1%
39	CaC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	130	400	Thermal CVD	—	—	CaO	—	1.0	1.0	-9.4%
40	SiC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	7	300	Plasma Enhanced CVD	—	—	—	—	0.9	0.9	-9.2%
41	SiC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	135	400	Thermal CVD	—	—	SiO <sub>2</sub>	—	0.7	0.7	-9.3%
42	—	7	300	Plasma Enhanced CVD	—	—	—	—	0.6	0.6	-9.1%
43	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	—	400	Thermal CVD	—	—	BeO	—	0.8	0.8	-9.1%
44	—	7	300	Plasma Enhanced CVD	—	—	—	—	0.7	0.7	-9.0%
45	MeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	185	300	Thermal CVD	1.5	2.5	MoO <sub>3</sub>	—	0.6	0.6	-8.5%
46	—	7	300	Plasma Enhanced CVD	—	—	—	—	0.5	0.5	-8.3%
47	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	150	400	Thermal CVD	1.3	2.4	BeO	—	0.8	0.8	-8.5%
48	CaC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	150	350	—	0.8	2.0	—	—	0.7	0.7	-9.0%
49	SiC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	195	—	—	—	—	SiO <sub>2</sub>	—	0.8	0.8	-9.0%
50	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	200	350	—	0.8	2	BaO	—	0.7	0.7	-9.5%
51	MeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	115	350	Plasma Enhanced CVD	0.5	1.5	MoO <sub>3</sub>	—	0.7	0.7	-8.8%
52	—	115	350	Thermal CVD	—	—	—	—	0.6	0.6	-8.5%
53	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	160	450	Thermal CVD	—	—	BeO	—	0.8	0.8	-8.5%
54	CaC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	120	—	—	—	—	CaO	—	0.6	0.6	-8.2%
55	SiC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	125	—	—	—	—	SiO <sub>2</sub>	—	0.5	0.5	-9.3%
56	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	130	—	—	—	—	BaO	—	0.4	0.4	-8.8%
57	MaC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	80	350	Plasma Enhanced CVD	—	—	MoO <sub>3</sub>	—	1.1	1.1	-7.5%
58	—	7	250	Thermal CVD	—	—	—	—	0.9	0.9	-7.1%
59	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	75	350	Plasma Enhanced CVD	—	—	BeO	—	1.2	1.2	-7.0%
60	—	7	250	Plasma Enhanced CVD	—	—	—	—	1.0	1.0	-6.5%
61	CaC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	90	350	Thermal CVD	—	—	CaO	—	0.9	0.9	-8.2%
62	—	7	250	Plasma Enhanced CVD	—	—	—	—	0.8	0.8	-8.3%
63	SiC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	95	350	Thermal CVD	—	—	SiO <sub>2</sub>	—	0.8	0.8	-8.9%
64	—	7	250	Plasma Enhanced CVD	—	—	—	—	0.7	0.7	-9.0%
65	BeC <sub>11</sub> H <sub>10</sub> O <sub>2</sub>	98	350	Thermal CVD	—	—	BeO	—	0.9	0.9	-8.0%
66	VAPOR DEPOSITING IRADIATING ELECTRON BEAM	350	—	VACUUM VAPOR DEPOSITION	—	—	—	—	0.7	0.7	-8.1%
67	SPUTTERING ON Mo	—	—	SPUTTERING	—	—	MoO <sub>3</sub>	III/IV face orientation	0.8	0.8	-15.2%
68	SCREEN PRINTING ON Mo	—	—	SCREEN PRINTING	—	—	—	III/IV face orientation	0.5	0.1	-0.2%
69	SCREEN PRINTING ON Mo	—	—	SCREEN PRINTING	—	—	—	III/IV face orientation	—	—	-25.1%
											6.5%
											10.8%

**Claims**

1. A plasma display panel including a plurality of discharge space cells and a protecting layer of an alkaline earth oxide having one of a (100) crystal face orientation and a (110) crystal face orientation on a surface of a dielectric layer (13) of a substrate (11).
2. The plasma display panel of Claim 1, wherein each cell is pressurized to a pressure in the range of 500Torr (66.5kPa) to 760Torr (101 kPa).
3. The plasma display panel of Claim 2, wherein each cell is charged with a xenon discharge gas in a range from 10% by volume to 100% by volume.
4. The plasma display panel of Claim 3, wherein one of argon, krypton, helium and neon is mixed with the xenon.
5. The plasma display panel of Claim 3, wherein argon or krypton is mixed with the xenon in sufficient volume to increase ultraviolet light emission at a wavelength of 173 nm.
6. The plasma display panel of Claim 3, wherein two additional discharge gases selected from argon, krypton, helium and neon are mixed with the xenon in a range from 10% to 50% by volume.
7. The plasma display panel of Claim 2, having display electrodes (12), wherein a distance between display electrodes in the same plane is no greater than 0.1 mm.
8. The plasma display panel of Claim 1, wherein the protecting layer is formed from an alkaline earth oxide with (100) crystal face orientation selected from MgO, BeO, CaO, SrO and BaO.
9. The plasma display panel of Claim 1 wherein the protecting layer is magnesium oxide with a crystal face orientation of (110).
10. A method of producing a plasma display panel having a plurality of discharge space cells, comprising the steps of:
  - depositing a protecting layer of an alkaline earth oxide having one of a (100) crystal face orientation and a (110) crystal face orientation on a surface of a dielectric layer (13) of a first substrate (11); and
  - introducing a discharge gas into each cell.
11. The method of Claim 10 wherein each cell is pressurized to a pressure in the range of 500Torr (66.5kPa) to 760Torr (101 kPa).
12. The method of Claim 11 wherein each cell is charged with a xenon discharge gas in a range from 10% by volume to 100% by volume.
13. The method of Claim 12 wherein one of argon, krypton, helium and neon is mixed with the xenon.
14. The method of Claim 12 wherein argon or krypton is mixed with the xenon in sufficient volume to increase ultraviolet light emission at a wavelength of 173 nm.
15. The method of Claim 12 wherein two additional discharge gases selected from argon, krypton, helium and neon within the range of 10% to 50% by volume are mixed with the xenon.
16. The method of Claim 10 wherein the protecting layer is formed from an alkaline earth oxide with (100) crystal face orientation selected from MgO, BeO, CaO, SrO and BaO.
17. The method of Claim 10 wherein the protecting layer is magnesium oxide with a crystal face orientation of(110).
18. The method of Claim 10, wherein the dielectric layer (13) is heated to a temperature between 350°C to 400°C during the depositing of the protecting layer by a thermal chemical vapor deposition.
19. The method of Claim 10 wherein the dielectric layer (13) is heated to a temperature between 250°C to 300°C

during the depositing of the protecting layer by a plasma chemical vapor deposition.

20. The method of Claim 10 wherein the first substrate (11) includes a glass plate and display electrodes (12) are formed by depositing a conductive paste on the glass plate, and wherein the paste is then baked to be hardened  
5 and the display electrodes subsequently are sandwiched between the glass plate and the dielectric layer (13).

21. The method of Claim 10 wherein the protecting layer is deposited by transferring a paste of the alkaline earth oxide to the dielectric layer (13) and baking it.

10 22. The method of Claim 21 wherein the paste is a magnesium salt with a plate-shaped crystal structure.

23. The method of Claim 22 wherein the paste is magnesium oxalate formed by dissolving ammonium oxalate in a magnesium chloride aqueous solution and heating it to form the plate-shaped crystal structure.

15 24. The method of Claim 10 wherein the depositing of the protecting layer is made by evaporating the alkaline earth oxide with an ion/electron beam in a vacuum.

25. A method of producing a plasma display panel having a plurality of discharge space cells, comprising the steps of:

20 depositing a protecting layer of an alkaline earth oxide selected from the group consisting of  $M(C_{11}H_{19}O_2)_2$ ,  $M(C_5H_7O_2)_2$ ,  $M(C_5H_5F_3O_2)_2$ , and  $M(C_5H_5)_2$ , wherein M represents one of magnesium, beryllium, calcium, strontium, and barium, the protecting layer having one of a (100) crystal-face orientation and a (110) crystal-face orientation extending across a surface of each cell; and  
introducing a discharge gas into each cell.

25 26. The method of Claim 25, wherein the protecting layer is deposited by one of a thermal chemical vapor deposition step and a plasma enhanced chemical vapor deposition step.

30 27. The method of Claim 25 or Claim 26 wherein the discharge gas includes at least 10% by volume Xc and is pressurized to a pressure in the range of 500Torr (66.5 kPa) to 760Torr (101kPa).

28. The method of Claim 27, wherein the discharge gas includes one of Ar and Kr.

35 29. The method of Claim 27, wherein the discharge gas is selected from a group consisting of Ar-He-Xe, Ar-Ne-Xe, Kr-Ne-Xe, and Kr-He-Xe and the amount of Kr, Ar, He, or Ne is in the range of 10% to 50% by volume.

30 30. The method of Claim 27, wherein the alkaline earth oxide is selected from the group consisting of magnesium dipivaloyl methane, magnesium acetylacetone, magnesium trifluoroacetylacetone, and cyclopentadienyl magnesium.

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Fig. 1

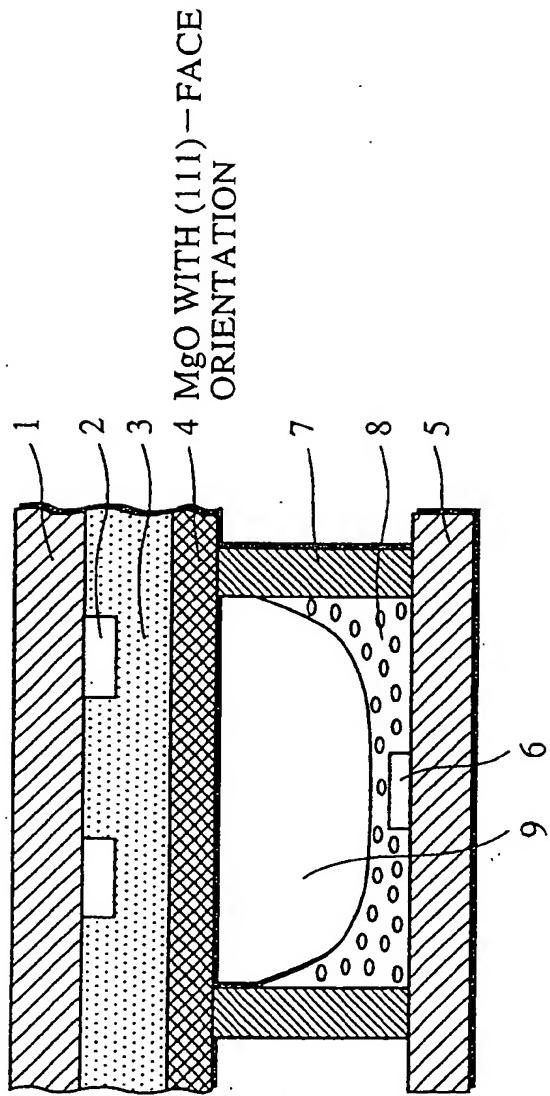


Fig. 2

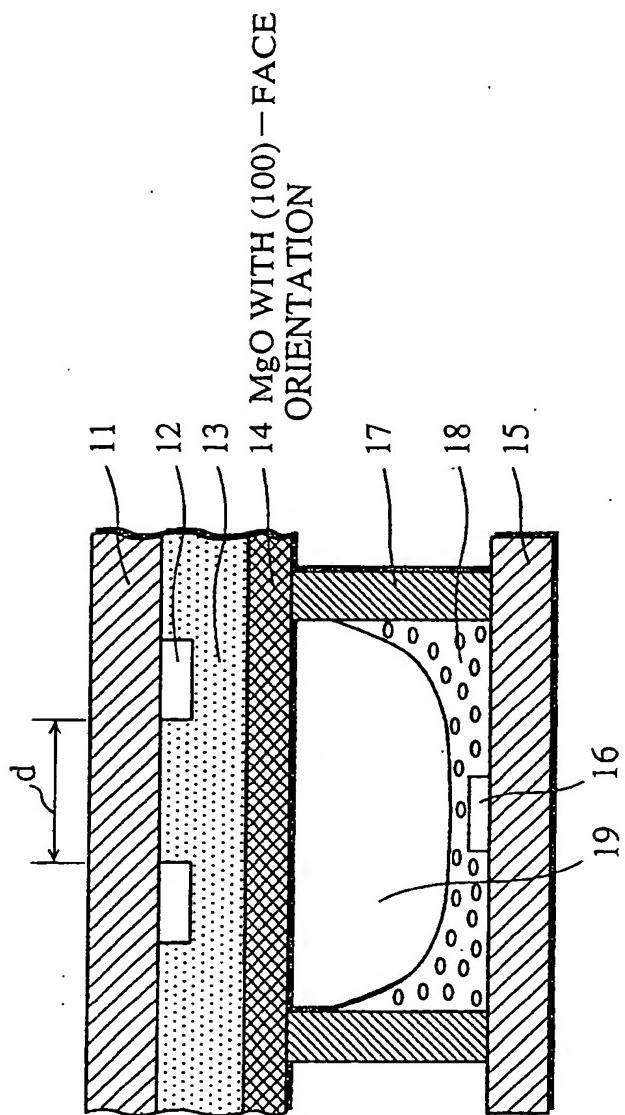


Fig. 3

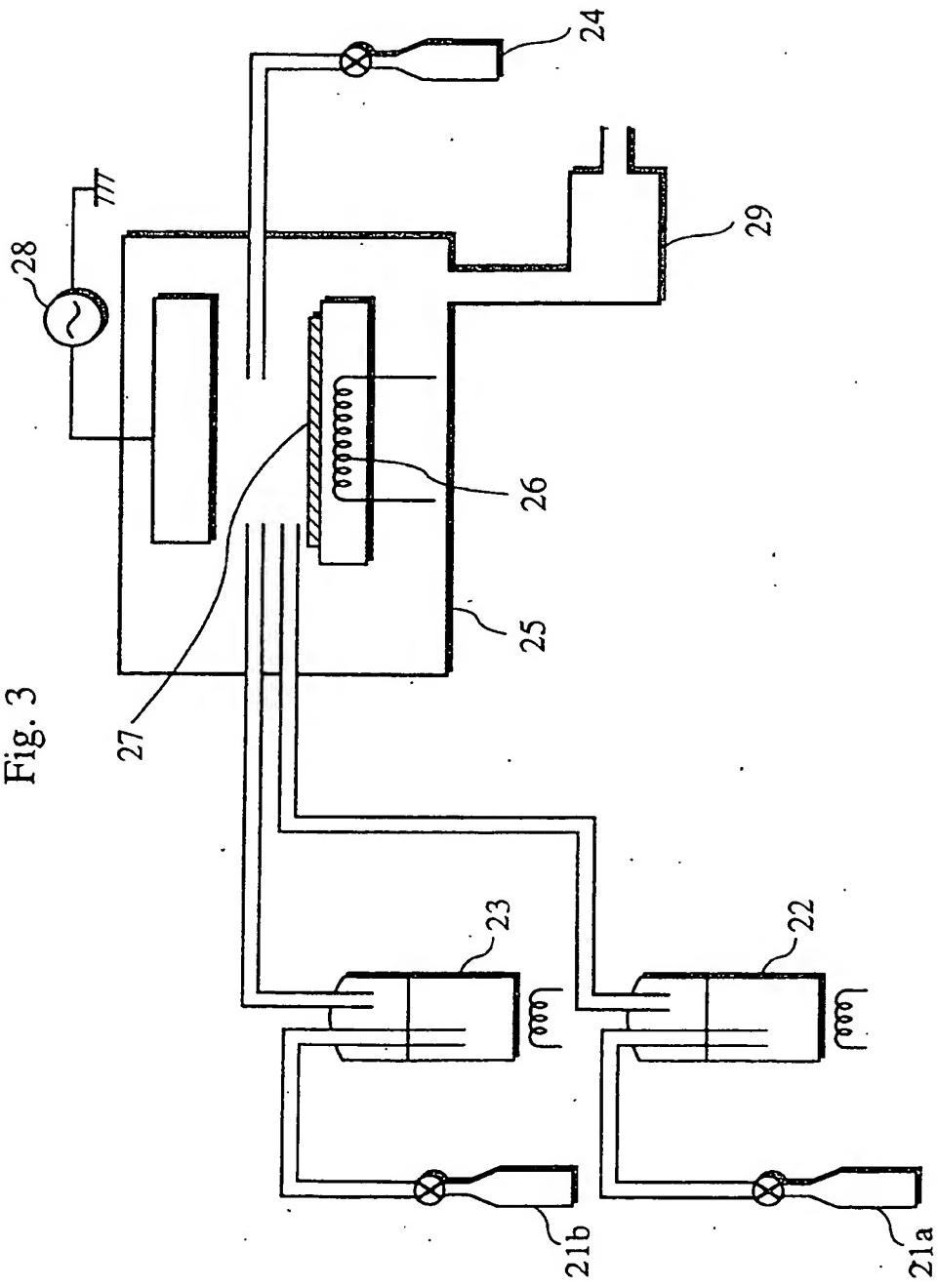


Fig. 4

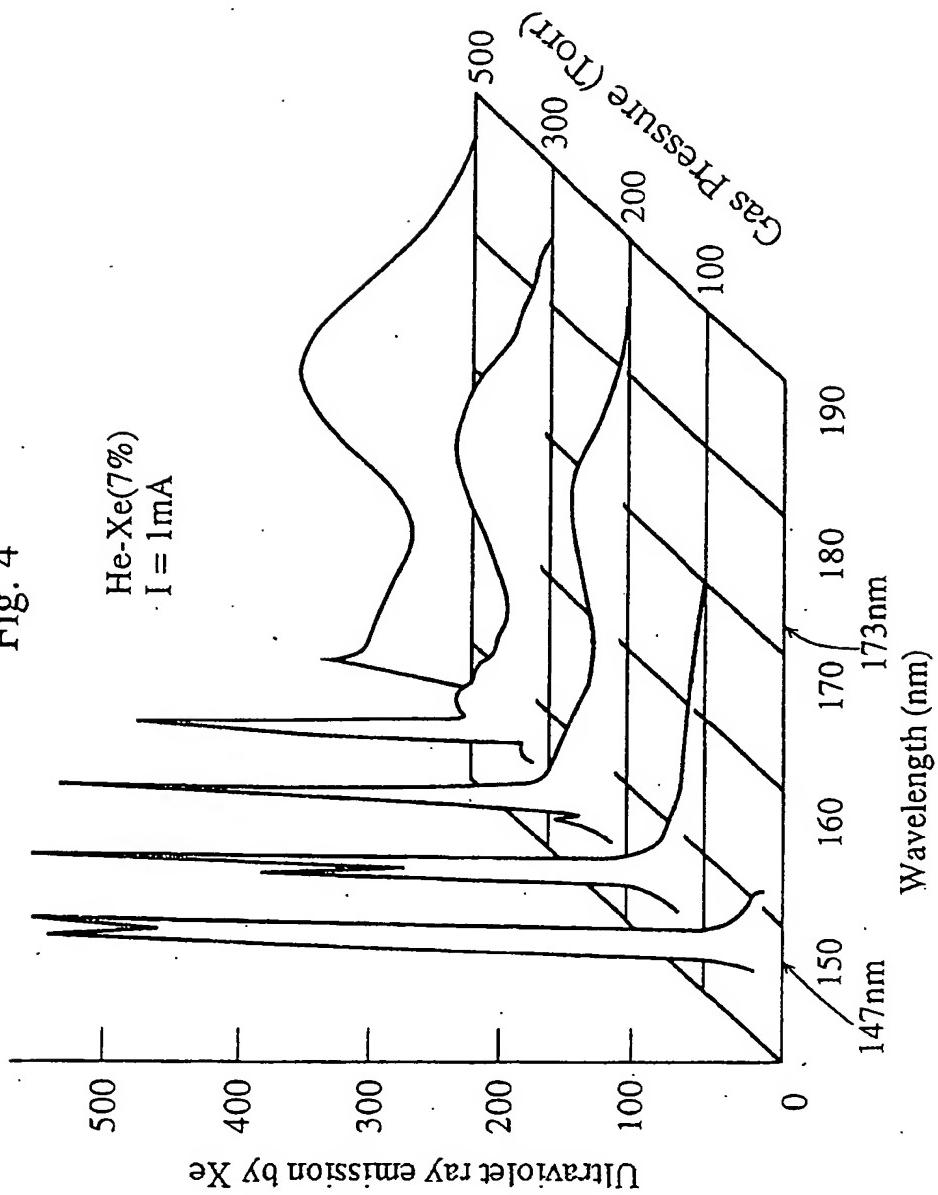


Fig. 5(a)

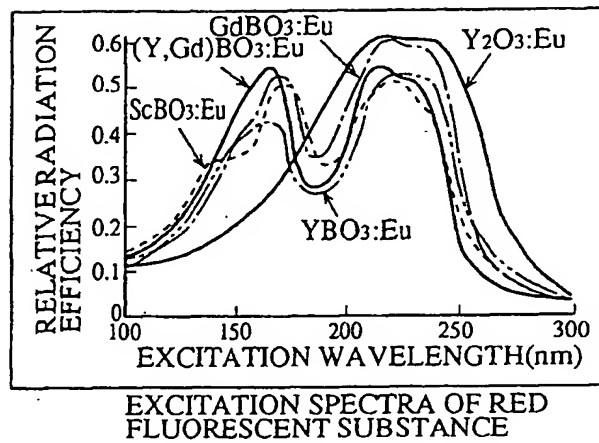


Fig. 5(b)

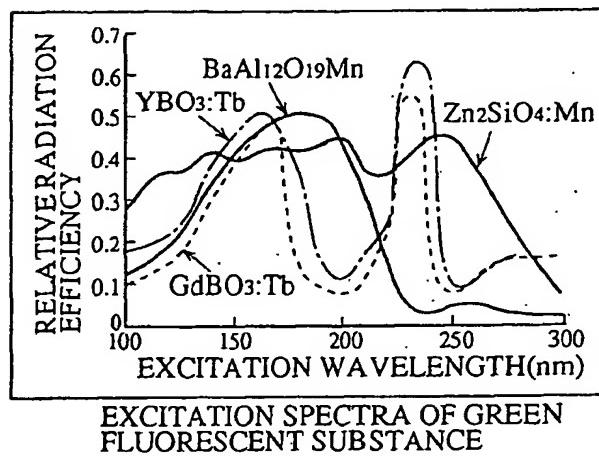


Fig. 5(c)

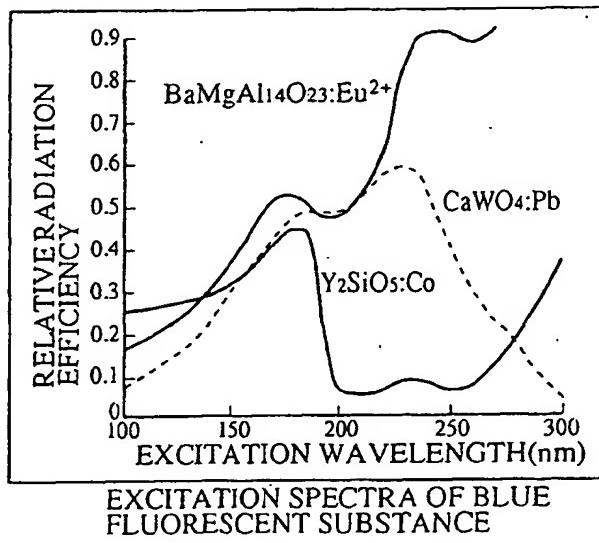


Fig. 6

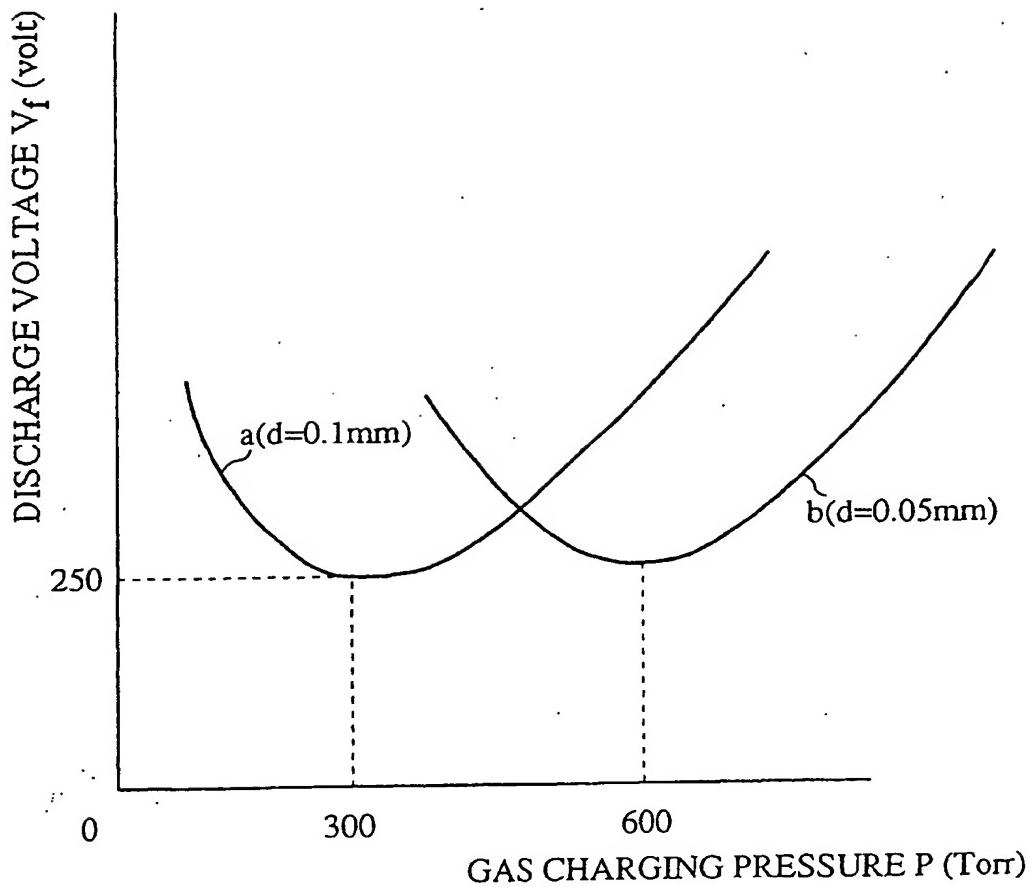
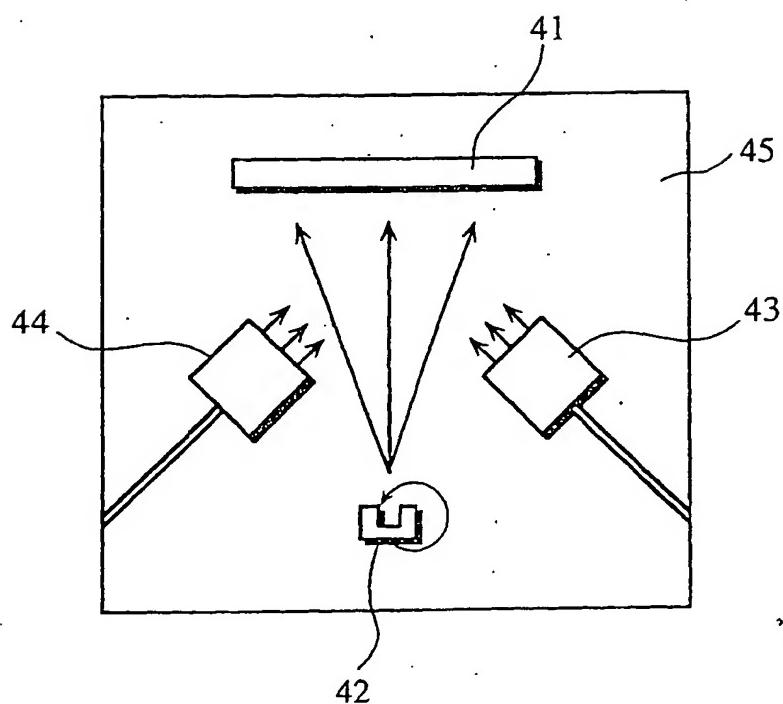


Fig. 7





(19)

Europäisches Patentamt  
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(11)

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(12)

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18.12.2002 Bulletin 2002/51

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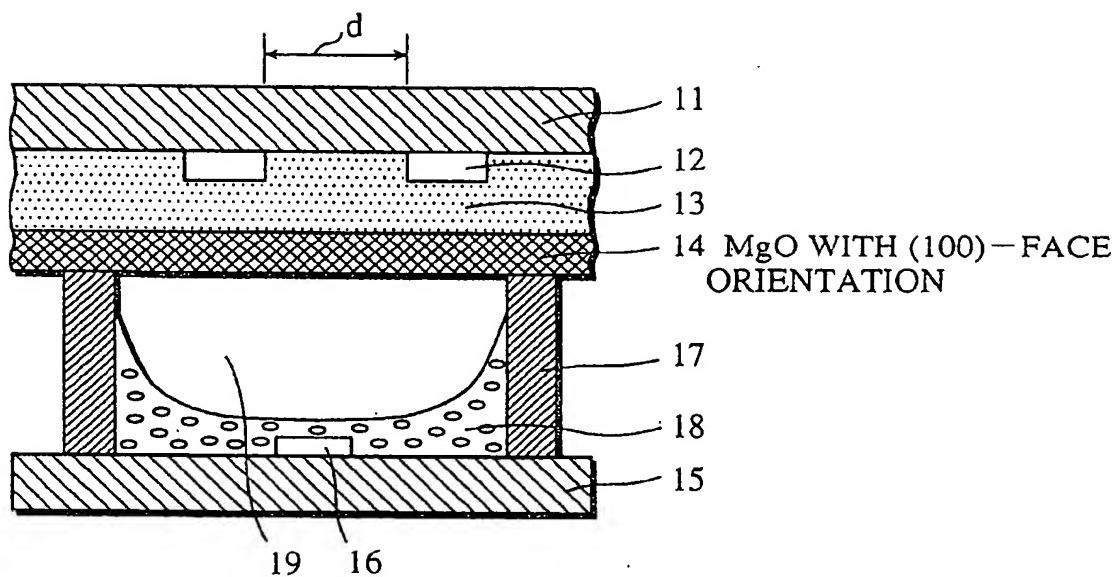
(74) Representative: Butcher, Ian James et al  
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## (54) Plasma display panel suitable for high-quality display and production method

(57) The first object of the present invention is to provide a PDP with improved panel brightness which is achieved by improving the efficiency in conversion from discharge energy to visible rays. The second object of the present invention is to provide a PDP with improved panel life which is achieved by improving the protecting layer (14) protecting the dielectric glass layer (13). To achieve the first object, the present invention sets the amount of xenon in the discharge gas to the range of 10% by volume to less than 100% by volume, and sets the charging pressure for the discharge gas to the range of 500 to 760Torr which is higher than conventional charging pressures. With such construction, the panel

brightness increases. Also, to achieve the second object, the present invention has, on the surface of the dielectric glass layer (13), a protecting layer (14) consisting of an alkaline earth oxide with (100)-face or (110)-face orientation. The protecting layer (14), which may be formed by using thermal Chemical Vapor Deposition (CVD) method, plasma enhanced CVD method, or a vapor deposition method with irradiation of ion or electron beam, will have a high sputtering resistance and effectively protects the dielectric glass layer (13). Such a protecting layer (14) contributes to the improvement of the panel life.

Fig. 2



European Patent  
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## EUROPEAN SEARCH REPORT

Application Number  
EP 02 00 6620

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
E	US 6 160 345 A (AOKI MASAKI ET AL) 12 December 2000 (2000-12-12) * column 5, line 63 - column 6, line 23 * * column 7, line 52 - line 62 * ---	1,10,25	H01J17/49 C03C17/34
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Y	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 03, 29 March 1996 (1996-03-29) & JP 07 300397 A (MATSUSHITA ELECTRIC IND CO LTD), 14 November 1995 (1995-11-14) * abstract *	1,10,25	
A	US 5 139 999 A (BURIAK JILLIAN M ET AL) 18 August 1992 (1992-08-18) * column 3, line 45 - column 4, line 47 * ---	1,10,25	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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<p>The present search report has been drawn up for all claims</p> <p>Place of search: THE HAGUE Date of completion of the search: 28 October 2002 Examiner: F de Ruyter-Noordman</p> <p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background C : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 02 00 6620

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 562 (C-665), 13 December 1989 (1989-12-13) & JP 01 234398 A (MATSHITA ELECTRIC IND CO LTD), 19 September 1989 (1989-09-19) * abstract * -----	1,10	
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The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	28 October 2002	F de Ruyter-Noordman	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 02 00 6620

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
 The members are as contained in the European Patent Office EDP file on  
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28-10-2002

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PUBLICATION NUMBER : 06325696  
PUBLICATION DATE : 25-11-94

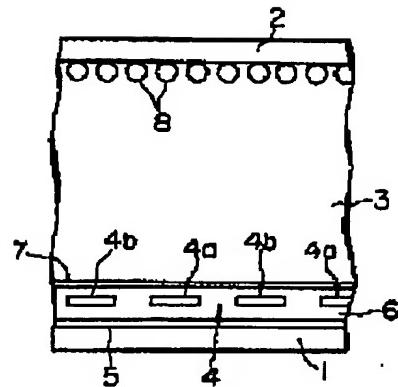
APPLICATION DATE : 10-05-93  
APPLICATION NUMBER : 05108579

APPLICANT : DAINIPPON PRINTING CO LTD;

INVENTOR : ISHIDA YUKIO;

INT.CL. : H01J 11/02 H01J 9/02 H01J 9/20  
H01J 11/00

TITLE : AC TYPE PLASMA DISPLAY AND  
MANUFACTURE THEREOF



ABSTRACT : PURPOSE: To provide an ac type plasma display, which can be formed thin and which can impart the lowering of the discharge starting voltage and the driving voltage (power consumption) and which can be manufactured at a low cost.

CONSTITUTION: Multiple crystal single sheet type MgO, which is formed by heat treatment of magnesium hydroxide, is mixed in the vehicle at 1-20% solid ratio. The surface of a dielectric layer 6 is coated with the paste having 3-15 $\mu$ m grain diameter by the screen printing, and thereafter, the surface coated with the paste is baked to obtain a protecting layer 7 made of MgO.

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(19)日本国特許庁 (JP)

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(11)特許出願公開番号

特開平6-325696

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9/02	F 7354-5E			
9/20	A 7250-5E			
11/00	K 9376-5E			

審査請求 未請求 請求項の数 5 OL (全 7 頁)

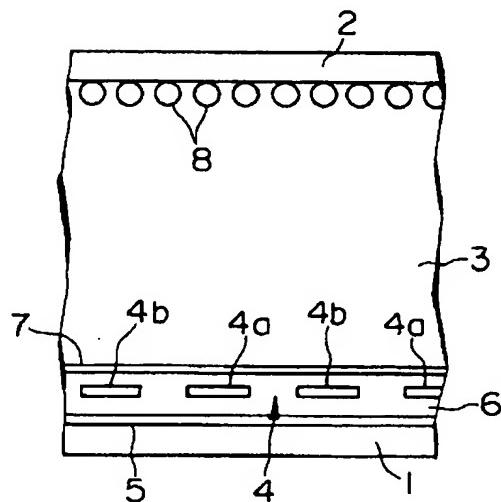
(21)出願番号	特願平5-108579	(71)出願人	593088234 内池 平樹 広島県広島市西区井口鈴が台1丁目8番11号
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		(74)代理人	弁理士 志賀 正武 (外2名)
			最終頁に統ぐ

(54)【発明の名称】 a c形プラズマディスプレイおよびその製造方法

(57)【要約】

【目的】 薄化とともに放電開始電圧や駆動電圧(消費電力)の低下が図られ、しかも低コストで製造を可能とするa c形プラズマディスプレイを提供する。

【構成】 水酸化マグネシウムを熱処理して生成した多結晶片葉形のMgOを、ビヒクル中への混入比を固形分比1~20%とするとともに、その粒径を3~15μmとしたペーストを、誘電体層6の表面にスクリーン印刷法により塗布し、この後焼成することによりMgOからなる保護層7を得る。



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## 【特許請求の範囲】

【請求項1】 ガス放電空間を挟んで背面基板と前面基板が対向配置され、少なくとも一方の基板には、誘電体層に覆われた互いに対となる電極がそれぞれ形成されるとともに、誘電体層の上には保護層が形成されてなるa c形プラズマディスプレイにおいて、前記保護層は、ビヒクル中に多結晶片葉形のMgOが混入されたペーストを塗布してなるMgO層であることを特徴とするa c形プラズマディスプレイ。

【請求項2】 前記ビヒクル中への前記多結晶片葉形のMgOの混入比が、重量比1～20%であることを特徴とする請求項1または請求項2記載のa c形プラズマディスプレイ。

【請求項3】 前記多結晶片葉形のMgOの粒径が、3～15μmであることを特徴とする請求項1または請求項2記載のa c形プラズマディスプレイ。

【請求項4】 前記多結晶片葉形のMgOの結晶は、水酸化マグネシウムを熱処理して生成したものであることを特徴とする請求項1または請求項2記載のa c形プラズマディスプレイ。

【請求項5】 請求項1または請求項2記載のa c形プラズマディスプレイにおいて、ビヒクル中に多結晶片葉形のMgOを混入したペーストを、前記誘電体層の表面に対し厚膜印刷法を用いて塗布することにより、前記保護層を形成することを特徴とするa c形プラズマディスプレイの製造方法。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】 本発明は、a c形プラズマディスプレイおよびその製造方法に係り、特に誘電体層の表面に形成する保護層の形成技術に関する。 30

## 【0002】

【従来の技術】 放電に伴う発光現象をディスプレイに利用するいわゆるプラズマディスプレイは、電極の構造から、放電空間に金属電極が露出しているd c形と、金属電極が誘電体層で覆われているa c形とに大別されるが、薄型かつ大画面のカラーテレビに用いる場合には、メモリ機能を有して大型化に対応可能なa c形が好適である。このa c形プラズマディスプレイは、電極の配置構造から、面放電方式と対向電極方式とに分けられるが、いずれの方式においても、前記誘電体層の表面には保護層（主としてMgO層）を形成している。

【0003】 この保護層の形成方法は、薄膜法としてEB蒸着法があり、厚膜法としてMgO原料である塩基性炭酸マグネシウムをスプレーで層形成した後に熱処理してMgO層とする方法がある。（参考公報：特公昭60-42579号、特公昭63-59221号、特公昭57-13983号）。また、これらの他に考えられる方法として、スパッタ法、CVD法、スクリーン印刷法等がある。

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## 【0004】

【発明が解決しようとする課題】 上記各方法のうち、特にスクリーン印刷法は、手軽な方法であることから観意検討がなされてきたにもかかわらず、性能上の目的を達するには至っていない。その理由としては、過去に試作あるいは市販されてきたMgOが混入されたペーストが有する性質が製造のプロセスに合致せず、必要なディスプレイのパネル特性を得られない為と判明した。そして、過去に市販されたMgOペーストの造膜メカニズムは、金属有機化合物の熱分解によるMgO層の形成であり、通常の熱処理プロセス（600℃以下）では結晶面の生成が不十分であったり、熱分解時に膜に亀裂を生じたりといった問題を有するとともに、印刷性についても決して満足できるものではなかった。さらに、MgOの結晶構造上、層厚の薄化が困難であり、これにともなつて放電開始電圧や駆動電圧をなるべく低下させたいにもかかわらずそれが実現できない不都合があった。

【0005】 本発明は、上記事情に鑑みてなされたものであって、薄化とともに放電開始電圧や駆動電圧（消費電力）の低下が図られ、しかも低コストで製造を可能とするa c形プラズマディスプレイおよびその製造方法を提供することを目的としている。

## 【0006】

【課題を解決するための手段】 本発明は上記目的を解決するためになされたもので、請求項1のa c形プラズマディスプレイは、ガス放電空間を挟んで背面基板と前面基板が対向配置され、少なくとも一方の基板には、誘電体層に覆われた互いに対となる電極がそれぞれ形成されるとともに、誘電体層の上には保護層が形成されてなるa c形プラズマディスプレイにおいて、前記保護層を、ビヒクル中に多結晶片葉形のMgOが混入されたペーストを塗布してなるMgO層で構成したことを特徴としている。

【0007】 また請求項2として、請求項1または請求項2記載のa c形プラズマディスプレイにおいて、前記ビヒクル中への前記多結晶片葉形のMgOの混入比を、重量比1～20%としたことを特徴としている。

【0008】 また請求項3として、請求項1または請求項2記載のa c形プラズマディスプレイにおいて、前記多結晶片葉形のMgOの粒径を、3～15μmとしたことを特徴としている。

【0009】 また請求項4として、請求項1または請求項2記載のa c形プラズマディスプレイにおいて、前記多結晶片葉形のMgOの結晶を、水酸化マグネシウムを熱処理して生成したものとしたことを特徴としている。

【0010】 また請求項5のa c形プラズマディスプレイの製造方法は、請求項1または請求項2記載のa c形プラズマディスプレイにおいて、ビヒクル中に多結晶片葉形のMgOを混入したペーストを、前記誘電体層の表面に対し厚膜印刷法を用いて塗布することにより、前記

保護層を形成することを特徴としている。

【0011】

【作用】本発明のa c形プラズマディスプレイによれば、誘電体層を覆う保護層が、ビヒクル中に多結晶片葉形のMgOが混入されたペーストを塗布してなるMgO層で構成したことにより、保護層の層厚が薄くなるにともなって放電開始電圧や駆動電圧の抑制が促進されて消費電力が大幅に低下し、かつディスプレイ自体の厚さの薄化が実現できる。

【0012】これに加え、ビヒクル中への多結晶片葉形のMgOの混入比を、重量比1～20%にすること、また、多結晶片葉形のMgOの粒径を、3～15μmにすること、あるいは多結晶片葉形のMgOの結晶を、水酸化マグネシウムを熱処理して生成したものとすることにより、適度の大きさのMgOの粒子となるべく積層されない状態で平面的に誘電体層の表面に形成され、その結果、上述の保護層の薄化や消費電力の低下がさらに促進される。ここで、ビヒクル中への多結晶片葉形のMgOの混入比が、重量比1%未満であると造膜が困難であり、20%より多いと層厚が厚くなり過ぎる。また、MgOの粒径が、3μm未満では比表面積が大きくなるため維持電圧が高くなり、15μmより大きいと印刷適性が悪くなる他、層厚が厚くなりすぎる。

【0013】また、本発明のa c形プラズマディスプレイの製造方法によれば、ビヒクル中に多結晶片葉形のMgOを混入したペーストを、誘電体層の表面に対し厚膜印刷法を用いて塗布することにより、保護層を形成するもので、厚膜印刷法は大面積に対し低成本で造膜が可能であるから、たとえば大画面（たとえば対角40インチ程度）のカラーテレビのディスプレイを低成本で製造するにあたってきわめて好適である。

【0014】

【実施例】以下、図面を参照して本発明の一実施例を説明する。図1は、本発明にもとづいて構成された、カラーテレビのディスプレイ（パネル）に適用される面放電方式のa c形プラズマディスプレイの概略構造を示しており、符号1、2は、それぞれガス放電空間3を挟んで互いに平行に対向配置された背面基板、前面基板である。これら基板1、2は所定厚さのガラスから構成されている。背面基板1の前面基板2に面する対向面には、X電極4aおよびY電極4bからなる電極対4およびアドレス電極5が形成されている。これら電極対4およびアドレス電極5は、ガラス製の誘電体層6で被覆されており、さらにこの誘電体層6は、MgO層からなる保護層7で被覆されている。また、一方の前面基板2の背面基板1に面する対向面には、蛍光体8が形成されている。

【0015】次に、図2は、本発明にもとづいて構成された、カラーテレビのディスプレイ（パネル）に適用される対向電極方式のa c形プラズマディスプレイの概略

構造を示している。このプラズマディスプレイは、ガス放電空間3を挟んでガラス製の背面基板1と前面基板2が対向配置され、各基板1、2の互いの対向面には、それぞれガラス製の誘電体層6に覆われたX電極4aおよびY電極4bが形成されているとともに、各誘電体層6は、MgO層からなる第1の保護層7で被覆されている。さらに、これら第1の保護層7の表面には蛍光体8が形成され、これら蛍光体8は第2の保護層7で被覆されている。なお、この場合上下いずれにも蛍光体8が形成されているが、場合によっては上下いずれか一方に形成する。

【0016】さて、上記の各a c形プラズマディスプレイにおける保護層6は、以下のようにして形成されている。

【0017】①MgO粉末の生成条件

市販試薬1級の水酸化マグネシウムの粉末に対して650℃で1時間キープの熱処理を施し、これを今回のMgOの使用原料とする。このような生成条件によって得られたMgOは、多結晶葉片状（平べったい形状）を呈するとともに、その粒径は、3～15μmとなる。水酸化マグネシウムの脱水分解温度は350℃であるが、必要とする結晶すなわち粒径が3～15μmで多結晶葉片状の結晶を得るために加熱処理温度は、少なくとも600℃以上が必要であり、さらに、650℃近辺が好適である。

【0018】

②前記誘電体層6へのMgO層（保護層7）の形成  
適度な粘性を持ったビヒクル（例えばブチルカルピートールにエチルセルロースを溶解した増粘材）中に生成したMgO粉末を混入してペーストを得る。ビヒクル中へのMgO粉末の混入比は、重量比が1～20%、好ましくは10%前後となるようにする。

【0019】次に、このMgOペーストを、誘電体層6の表面に対し、厚膜印刷法の一種であるスクリーン印刷法を用いて大気中で塗布する。この場合、スクリーン（メッシュ）の粗さは、メッシュNo350、400の2種類が好適である。このようにスクリーン印刷法でMgOペーストを誘電体層6の表面に印刷したら、500℃で30分キープの熱処理（焼成）を施す。この後、水分を最終的に水蒸気として気化させる後処理として適宜加熱温度でベーキングを施す。

【0020】以上により、MgOよりなる前記保護層7が形成されるが、スクリーン印刷法で形成するこの保護層7は、薄膜法による造膜法に比較すると、大面積に対し低コストで造膜が可能であるから、たとえば大画面（たとえば対角）のカラーテレビのディスプレイを低成本で製造できる。

【0021】また、上記①の生成条件で生成したMgO粉末を、上記②の形成条件で誘電体層6に対して塗布・焼成して保護層7を形成することにより、多結晶葉片状

のMgO粒子は、誘電体層6の表面上においてその面方向が誘電体層6と平行な状態に積層し、その結果、保護層7の層厚をきわめて薄くすることができる。

【0022】一般にa c形プラズマディスプレイの保護層は、 $2\mu m$ 以下の層厚で形成することが実用上もっとも必要充分な条件とされているが、この $2\mu m$ の層厚を、上記方法では充分に形成し得る。その保護層7の層厚であるが、層厚がたとえば $10\mu m$ 程度と厚いと、a c形プラズマディスプレイの重要な特性の一つであるメモリ機能の発生源である壁電荷の効果を弱めることになって駆動電圧を高くする必要が生じ、その結果として、駆動回路に用いるトランジスタの電圧を高耐圧仕様にせねばならなくなる。

【0023】ところが、上記実施例のごとく形成したMgOの保護層7は、多結晶葉片状のMgO粒子の積層であることに加え、スクリーン印刷法による層厚コントロールがなされることにより、 $2\mu m$ 程度の層厚の形成が可能で、しかも結晶に亀裂が生じても誘電体層6が露出するおそれがない。このように保護層7の層厚を薄くできることにより、駆動電圧の低下を促進できてコスト低下を実現できるとともに、ディスプレイ自体の厚さをきわめて薄くできることが可能となる。

【0024】さらに保護層7の層厚に関して言及すると、a c形プラズマディスプレイにおける保護層は、一般に、絶縁層に対する希ガスイオンの衝撃からの保護と、2次電子放出能を高めるという2つの役目を持っているが、MgO粒子に重なりが少なくなるにしたがい放電電圧が低下するものの、誘電体としての作用の面からは粒子間の空隙が多いほど低誘電性となり放電電圧は上昇すると考えられる。したがって本実施例の場合であれば、比較的大きな多結晶葉片状のMgO粒子が1個ずつ空隙がない状態で平面的に並ぶことが望ましい。これとは逆に、球形あるいは不定形の微粒子であると、どうしても粒子相互の重なりは避けられず、結果的に、放電動作時に発生する二次電子は層内部にも多く伝搬しロスになると考えられ、さらには、前述の後処理におけるペーリングの際に、粒子間の水分の揮発性に劣るであろう。

【0025】「実験例」さて、図3および図4は、それぞれ上記実施例方法によって形成したMgO層（MgOは市販試薬1級の水酸化マグネシウムの粉末に対して $650^{\circ}C$ で1時間キープの熱処理を施した後ペーリングし、これをペーストとしたものをスクリーン印刷後、 $500^{\circ}C$ で焼成）のSEM写真像であり、図3のMgO層は、本発明にもとづく粒径が $3 \sim 15\mu m$ のMgO粒子が平面的に配された状態、図4のMgO層は粒径が $0.5 \sim 3\mu m$ のMgO粒子がランダム的に配された状態となっている。まず、図3および図4のMgO層をそれぞれ実験例1、比較例1とし、経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を図5に、また、電圧にともなう輝度Lと効率ηの比較を図6に示す。これ

らを見ると、まず比較例1に比べると実験例1は低い電圧で稼働するとともに寿命が長く、また、低い電圧にもかかわらず輝度および効率が高いといった優位性が認められる。

【0026】次に、前記実験例1と、蒸着によって形成されたMgO層である比較例2との比較を図7および図8に示す。この場合、蒸着によるMgO層の比較例2よりも実験例1の方が寿命が長く、また、輝度Lに関しては同電圧においては比較例3が優位ではあるものの、効率では電圧が高いものの実験例1の方が優位であることが認められる。

【0027】次に、上記実験例1のMgO層の厚さを $2\mu m$ とした本発明にもとづく実験例2と、前記比較例2の経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を図9に示す。これを見ると、蒸着によって形成された比較例2のMgO層と実験例2とはほとんど同様の特性を示しており何ら差がないことがわかる。

【0028】次に、前記実験例2と、この実験例2と製法は同様であるが層厚を $10\mu m$ とした比較例3との電圧にともなう輝度Lと効率ηの比較を図10に示す。これによると、層厚の薄い実験例2の方が比較例3に比べると低電圧で高輝度、高効率が得られている。

【0029】次に、本発明にもとづいて前記ビヒクル中のMgOの混入比を、重量比10%とした実験例3と、重量比40%とした比較例4との経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を図11に、また、電圧にともなう輝度Lと効率ηの比較を、図12に示す。これによると、重量比10%の実験例3の方が重量比40%の比較例4に比べると低電圧で稼働し、また、低電圧で高輝度、高効率が得られている。

【0030】上記各実験を総合すると、保護層としてのMgO層は、多結晶片葉形のMgOの結晶が水酸化マグネシウムを熱処理して生成したものであること、そのMgOの粒径が、 $3 \sim 15\mu m$ であること、そして、ビヒクル中のMgOの混入比が重量比10%であることが保護層として充分な特性を発揮することが認められた。

### 【0031】

【発明の効果】以上説明したように、本発明のa c形プラズマディスプレイによれば、誘電体層を覆う保護層が、ビヒクル中に多結晶片葉形のMgOが混入されたペーストを塗布してなるMgO層で構成したことにより、保護層の層厚が薄くなるにともなって放電開始電圧や駆動電圧の抑制が促進されて消費電力が大幅に低下し、かつディスプレイ自体の厚さの薄化が実現できるといった効果を奏する。また、ビヒクル中の多結晶片葉形のMgOの混入比を重量比1~20%にすること、また多結晶片葉形のMgOの粒径を $3 \sim 15\mu m$ にすること、あるいは多結晶片葉形のMgOの結晶を水酸化マグネシウムを熱処理して生成したものとすることにより、適度の大きさのMgOの粒子がなるべく積層されない状態で平

7

面的に誘電体層の表面に形成され、その結果、上述の保護層の薄化や消費電力の低下がさらに促進される。

【0032】また、本発明のa c形プラズマディスプレイの製造方法によれば、ビヒクル中に多結晶片葉形のMgOを混入したペーストを、誘電体層の表面に対し厚膜印刷法を用いて塗布することにより保護層を形成することを特徴としており、厚膜印刷法は大面積に対し低コストで造膜が可能であるから、たとえば大画面（たとえば対角40インチ程度）のカラーテレビのディスプレイを低成本で製造するにあたってきわめて好適である。

【図面の簡単な説明】

【図1】 本発明の一実施例である面放電方式のa c形プラズマディスプレイの概略を示す断面図である。

【図2】 本発明の他の実施例である対向電極方式のa c形プラズマディスプレイの概略を示す断面図である。

【図3】 実験例1のMgO層のSEM写真像である。

【図4】 比較例1のMgO層のSEM写真像である。

【図5】 実験例1と比較例1の経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を示すグラフである。

【図6】 実験例1と比較例1の電圧にともなう輝度L

10

8

と効率ηの比較を示すグラフである。

【図7】 実験例1と比較例2の経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を示すグラフである。

【図8】 実験例1と比較例2の電圧にともなう輝度Lと効率ηの比較を示すグラフである。

【図9】 実験例2と比較例2の経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を示すグラフである。

【図10】 実験例2と比較例3の電圧にともなう輝度Lと効率ηの比較を示すグラフである。

【図11】 実験例3と比較例4の経時変化にともなう放電開始電圧V<sub>f</sub>と維持電圧V<sub>s m</sub>の比較を示すグラフである。

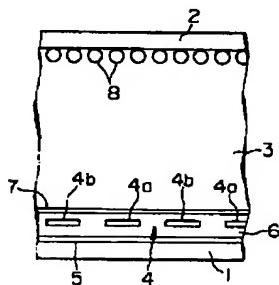
【図12】 実験例3と比較例4の電圧にともなう輝度Lと効率ηの比較を示すグラフである。

【符号の説明】

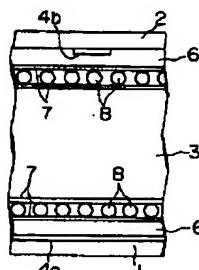
1…背面基板、2…前面基板、3…放電空間、4…電極対、4a…X電極、4b…Y電極、5…アドレス電極、6…誘電体層、7…保護層、8…蛍光体。

20

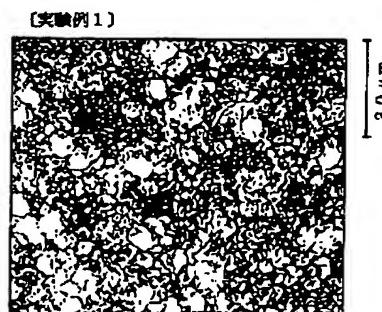
【図1】



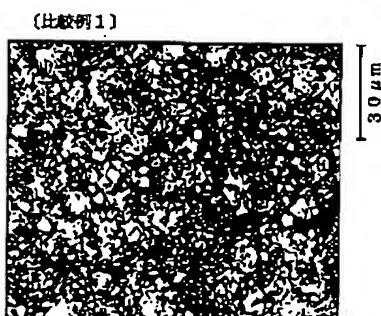
【図2】



【図3】

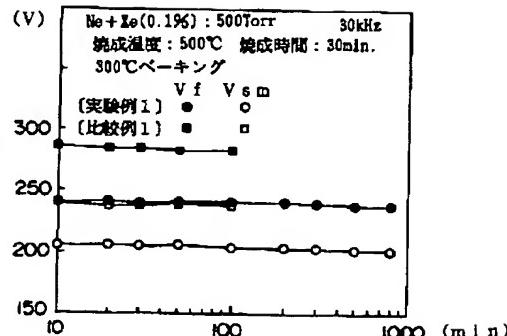


【図4】

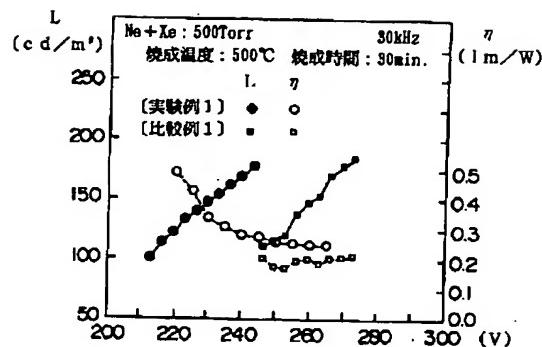


(比較例1)

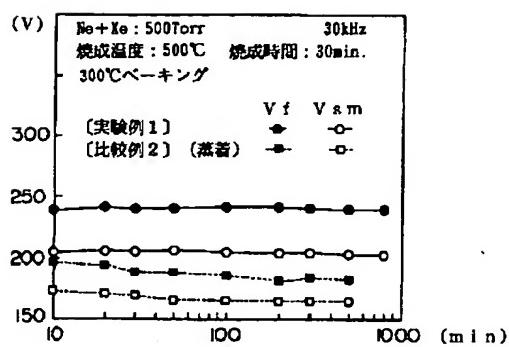
【図5】



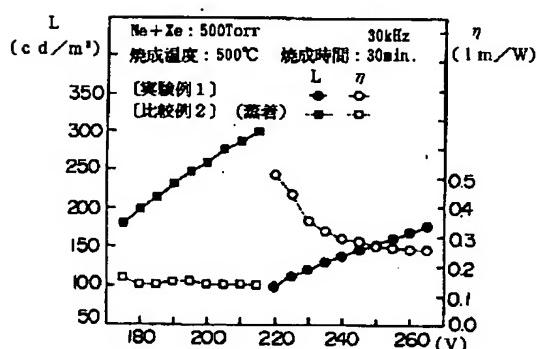
【図6】



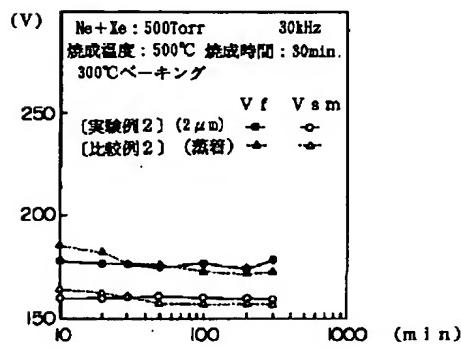
【図7】



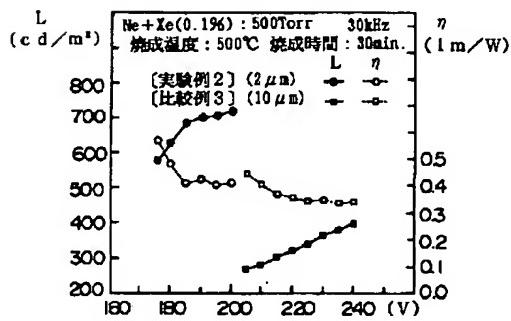
【図8】



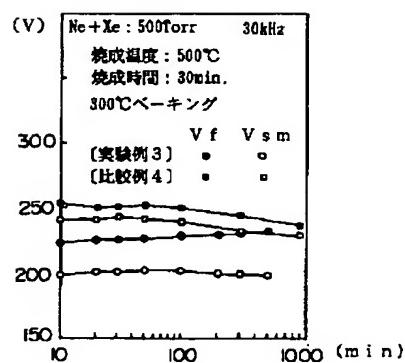
【図9】



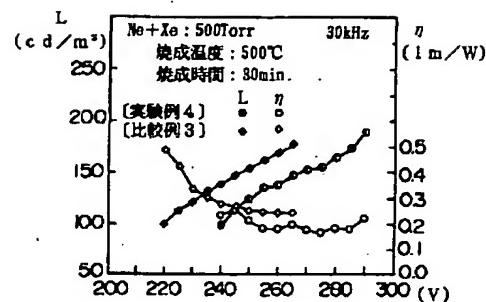
【図10】



【図11】



【図12】



フロントページの続き

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